Chapter 4
ANALYSIS AND EVALUATION OF MODEL RESULTS

ANALYTICAL PROCESS OVERVIEW

Both regional and subregional computer hydrologic simulations were used extensively by the South Florida Water Management District (District, SFWMD) to help develop the *Lower East Coast Regional Water Supply Plan* (LEC Plan). The South Florida Water Management Model version 3.7 (SFWMM) was used as the principal tool to evaluate overall regional performance, while subregional ground water models were used to simulate impacts at smaller scales, such as effects within service areas and impacts of individual wellfields. Data from SFWMM and subregional ground water model simulations were analyzed and interpreted to determine how to modify and improve the District's water management practices, the major features of the Central and Southern Florida Project for Flood Control and Other Purposes (C&SF Project), and local water management facilities to meet the future water needs of South Florida. First, present and future base case simulations of the regional SFWMM and the subregional ground water models were made to determine water requirements. From these model simulations it was possible to depict the historic and future water distribution to service areas, the frequency and severity of water shortages, and the ability to achieve environmental goals. This information was then used to evaluate the regional capacity and future water needs of the Lower East Coast (LEC) Planning Area. Second, the effects of the components recommended in the *Central and Southern Florida Project Comprehensive Review Study Final Feasibility Report and Programmatic Environmental Impact Statement* (Restudy) (USACE and SFWMD, 1999) that will be completed by 2020 were determined. Major features of the Restudy will dramatically affect water use and supply throughout the region. Analysis of the Restudy components included a similar examination of water distribution, water shortages, and the ability to achieve environmental restoration goals by 2020.

The LEC planning process then considered other options, either local water supply development or regional water resource development projects that could be implemented to meet future agricultural, urban, and environmental water supply needs by 2020. The planning goal of these efforts is that the local and regional projects combined should provide sufficient water to meet the 1-in-10 year level of certainty criteria for urban and agricultural water users, achieve the proposed minimum water level criteria, and substantially achieve long-term environmental restoration goals of the region. The ability to meet these demands, as identified in various statutes and mandates (meeting Minimum Flows and Levels, providing for public and agricultural water supply needs and achieving Everglades restoration), was evaluated for each model simulation using a comprehensive set of performance measures.

Data from local land use comprehensive plans, utilities, University of Florida Institute of Food and Agricultural Sciences (IFAS), and District permits were used to support these analyses and their assumptions. Conservative best professional judgement was used in circumstances where specific information was not available.

South Florida Water Management Model

The regional South Florida Water Management Model (SFWMM) was used to simulate the major components of the hydrologic cycle in South Florida including rainfall; evapotranspiration; infiltration; overland, ground water, and canal flow; canal-ground water and levee seepage; and ground water pumping. This large-scale (two-mile by two-mile grid size) regional model was developed specifically for the South Florida system, and is currently the best available tool that can simulate both the current and future operational complexities of the regional water control system and provide adequate technical information to make water management decisions (see **Chapter 2** and **Appendix E** for more information on the SFWMM). The base case simulations incorporated current or proposed water management control structures, operational rules, and water shortage policies. Daily hydrologic conditions were simulated using climate data for the 1965-1995 period of record, which includes droughts and wet periods.

Subregional Ground Water Models

Although the SFWMM is the principal tool used in the evaluation of the LEC Plan, five higher-resolution, subregional ground water flow models were developed as part of the planning process to evaluate potential benefits and impacts of specific options on local resources. Ground water models developed during this planning process include (1) the North Palm Beach Ground Water Model; (2) the South Palm Beach Ground Water Model; (3) the Broward Ground Water Model; (4) the North Miami-Dade Ground Water Model; and (5) the South Miami-Dade Ground Water Model. These models use the United States Geological Survey (USGS) modular three-dimensional finite difference ground water flow model, commonly known as MODFLOW. More information concerning these models is provided in **Chapter 2** and each model is described in greater detail in **Appendix F**.

The ground water models were also used to estimate the 1-in-10 year level of certainty for public and agricultural water uses. The simulation period of each model was January 1987 to December 1990. Results are reported only for the last two years to allow the models to warm up for one year. The simulation period from January 1989 to December 1990 contains rainfall deficient conditions that are approximately equivalent to a 1-in-10 year drought.

Other Models

Modeling was also used to analyze water availability and water demands in the Caloosahatchee Basin. These modeling efforts are described in the *Caloosahatchee Water Management Plan* (CWMP) (SFWMD, 2000d). Analytical tools used in this analysis included the Agricultural Field Scale Irrigation Requirements Simulation (AFSIRS) Model, the Water Management Optimization Model, and the MIKE SHE model. The AFSIRS is a surface water budget model which was used to approximate surface water availability in each of the major surface water subbasins in order to quantify the demands that could not be satisfied by surface water. The Water Management Optimization Model was used to determine how to best store and release water as needed to meet urban, agricultural, and environmental needs. The MIKE SHE model is an integrated surface water/ground water model that was used to identify potential impacts of water use on the environment and water resources.

RELATIONSHIP BETWEEN GOALS AND PLANNING CRITERIA

The model simulations were evaluated based on analysis of the planning criteria required by state statute (Section 373.036, F.S.):

- Provide for a 1-in-10 year level of certainty for users, without causing harm
- Protect water resources from significant harm
- Restore hydropatterns to water resources

The performance measures indicate the degree to which the water resource development projects and water supply options are likely to help meet these planning criteria and the goals and objectives of the LEC Plan. Performance measures are specific, selected, hydrologic targets that are outputs of the Natural System Model (NSM), SFWMM, and subregional ground water models. Results based on key performance measures that best summarize the performance of the simulations are presented later in this chapter.

PLANNING CRITERIA AND PERFORMANCE MEASURES

1-in-10 Year Level of Certainty

Each model requires a different approach to determine if a 1-in-10 year level of certainty can be met for urban and agricultural water users. In the Restudy, the 1-in-10 year level of certainty for water supply was determined based on a performance measure that considered the probability that water shortages would be declared during the 31-year period simulated by the SFWMM. An additional performance measure for 1-in-10 year level of certainty was developed for the LEC Plan analysis using the subregional models. Since the subregional ground water models were used to simulate a time period that included a 1-in-10 year, rainfall-deficit, drought condition, performance measures based on simulated ground water stages were used to determine how well local water demands were met during this drought period without causing harm to the environment.

Meeting 1-in-10 Year Level of Certainty for Water Supply During the 31-Year Period of Record

One measure of the ability to meet water supply demands for the Lake Okeechobee Service Area (LOSA) and Lower East Coast Service Areas (LECSAs) is if water supply restrictions can be avoided during the 31-year period of record except during the most severe droughts. State law enables the District to impose water restrictions during droughts to conserve regional water resources. The SFWMM mimics this policy by imposing restrictions on consumptive users when regional water supplies are diminished. Water demands are cut back when low ground water stages occur in selected trigger cells (based on historical monitoring well locations) located along the lower east coast of Florida, low stages in Lake Okeechobee or Water Conservation Area (WCA) canals, or due to continuation of the restriction in the dry season. The SFWMM restricts water supplies in each LEC service area if the LOSA is in Supply-Side Management for seven days consecutively during the dry season (October-May). The LOSA is placed on Supply-Side Management restrictions (or cutbacks) when Lake Okeechobee levels are expected to be lower than 11 ft NGVD at the end of the dry season (May 31). The Supply-Side Management criteria conserve water in the lake to meet crucial events in the future and, thereby, reduce the risk of serious or significant harm.

Results from the SFWMM are displayed for the LOSA and each LEC service area in a table format. The table displays the type, severity, and duration of cutbacks by water year (October-September). Types of cutbacks include those caused by Lake Okeechobee levels, low ground water levels along the coast, and dry season criteria. Water years are used, because counting water demand cutbacks by calendar year would, in some areas, double count events that extend throughout the dry season. The graphic summarizing these SFWMM results is entitled Frequency of Water Restrictions for the 1965-1995 Simulation Period (see **Figure D-1** in **Appendix D**).

The target for the LOSA and the LECSAs is to meet a 1-in-10 year level of certainty for water supply, as determined by counting the number of water years when significant water supply cutbacks occur due to exceeding Supply-Side Management criteria on the lake. A significant water supply cutback event occurs when the total volume of water not supplied to the LOSA exceeds approximately 100,000 acre-feet (ac-ft). To meet the 1-in-10 year level of certainly criterion in the LOSA and the LECSAs, significant water supply cutbacks should occur due to Lake Okeechobee stages in no more than three water years during the 31-year period of record.

For the LECSAs, additional information from the subregional ground water models is needed to assess local ground water conditions. The SFWMM's large cell size and emphasis on surface water hydrology limits its ability to simulate ground water levels and withdrawals along the coast near the model boundary. The ability of the SFWMM to distinguish between water stages at the trigger well and nearby withdrawal wells is limited because the trigger well and withdrawal wells can occur within the same model grid cell. More precise results can be achieved with the subregional ground water models.

Meeting the Level of Certainty for Water Supply During a 1-in-10 Year Drought Event

The second measure of the ability to meet water supply demands is to avoid water supply restrictions during a 1-in-10 year drought event due to low ground water stages along the coast. The subregional models approximate District water shortage policy by simulating restrictions on consumptive users. The ground water models simulate local conditions more accurately than the SFWMM, due to the smaller grid cell size. In addition, they can simulate ground water conditions including stratification of the aquifer.

In the subregional ground water models, the LECSAs are divided into Water Restriction Areas to more accurately reflect how the District's water shortage policy may be implemented. Results from ground water models are displayed spatially for each service area and as a table showing locations of trigger cells and the severity and duration of cutbacks by cause: Lake Okeechobee levels, low ground water levels along the coast, or dry season criteria. Information on cutbacks due to Lake Okeechobee stage is imported from the SFWMM to the subregional ground water models.

Due to the size and complexity of the subregional ground water models, they simulate a shorter period of record that includes a 1-in-10 year drought event. It begins June 1989 and ends May 1990 for North Palm Beach Service Area, LEC Service Area 1 (LECSA 1), and LEC Service Area 2 (LECSA 2). The rainfall drought for LEC Service Area 3 (LECSA 3) begins and ends one month earlier. Regional conditions are from the same historical period and are considered to be within the range of average regional flows from ground and surface water sources (see **Appendix I** for more information). To meet a 1-in-10 year level of certainty in LECSA, no water restrictions should occur during the 1-in-10 year drought event due to low ground water stages in selected trigger cells as simulated by the ground water models. The graphic summarizing these results is entitled Frequency and Severity of Water Restrictions by Water Restriction Area (see **Figure D-2** in **Appendix D**).

Saltwater Intrusion Analysis

Areas within the LEC Planning Area that have the highest potential for saltwater intrusion were determined using the following criteria:

- Water restriction frequency and duration
- Ground water stages as indicated by water shortage trigger wells
- Net westward ground water flow along the saline water interface

The application of water restrictions was discussed above. The two remaining factors are discussed below.

Water Levels as Indicated by Water Shortage Trigger Wells

Information about ground water stages at trigger wells is obtained as an output from the subregional ground water models. Ground water stages along the coast are indicative of changes elsewhere in the LEC Planning Area. Water shortage triggers, or water levels at which phased restrictions will be declared under the District's water shortage program, are used to curtail withdrawals by water use types. Such curtailment is imposed to avoid water levels declining to and below levels where serious or significant harm (i.e., saltwater intrusion) could potentially impact water resources (such as the Biscayne aquifer).

Saline Water Intrusion Criterion

The saline water intrusion criterion for the LEC Plan is defined as follows: water use withdrawals should not cause water flows towards the east in the Surficial Aquifer System to be less than the flows west near the saline water interface during a 12-month drought condition that occurs as frequently as once every 10 years. If ground water flow east towards the coast is less than the flow west, the saline interface has the potential to move. Ground water flows east were subtracted from the westward flows to calculate the net westward flow. Only positive flows (to the west) are shown in the performance measure graphic. The net flow is calculated for all layers of the models based on results of the subregional ground water models for the LECSAs.

This protection criterion is established to protect the quality and sustainability of the Surficial Aquifer System and to avoid impacts to existing users. The subregional ground water models used for the LEC Plan were not configured as chemical transport models and, therefore, cannot be used directly to simulated saline water intrusion. Instead, staff assumed that a net westward flow of water across the freshwater-saltwater interface is an indicator of potential intrusion. In general, proximity of a water use to the saline water interface necessitates a detailed evaluation prior to implementing an alternative or issuing a consumptive use permit. Given the regional nature of the plan, the ground water flow, water level, and water restriction analyses method were used to screen for the potential of coastal wellfields to induce westerly flow of saline water over large areas. Additional criteria or refinement of these methods will be applied during the Consumptive Use Permitting (CUP) process. See **Figure D-11** in **Appendix D** for an example of the output for this performance measure**.**

Isolated Wetland Protection Criteria

Criteria have also been defined for isolated wetlands which lie outside of the Everglades Protection Area in the LOSA and the LECSAs and are protected from harm due to water use permits up to 1-in-10 year droughts. The following criteria was applied to results from the subregional ground water models: ground water stage drawdowns induced by cumulative pumping withdrawals beneath wetlands should not exceed one foot at the edge of the wetland for more than one month during a 12-month drought condition that occurs as frequently as once every 10 years. For planning purposes, this criterion was applied to surficial aquifer drawdowns in areas that have been classified as wetlands according to the National Wetlands Inventory (NWI). The NWI cover was partially updated to reflect land use changes, primarily urban development, near wellfields. See **Figure D-10** in **Appendix D** for an example of the output from this performance measure.

Because of variations in methods used to identify and characterize wetlands, as well as temporal changes that occur in wetland characterization resulting from environmental resource mitigation activities, maintaining a detailed regional geographic inventory of local wetland conditions is difficult and beyond the scope of this plan. Instead, the best available geographic data was compiled and processed to provide a reasonable representation of wetland locations. In practice, implementation of the LEC Plan will require an inventory of potentially affected wetlands for protection or mitigation. Further, the criteria used for the LEC regional water supply planning analysis are not the same as the criteria used in the CUP Program. The CUP criteria will undergo rulemaking as part of the implementation of the District's regional water supply plans. The LEC Plan's criteria are used as a screening tool to alert future permittees of the need to evaluate wetlands in the vicinity of proposed withdrawals. More information regarding future rulemaking is included in **Chapter 5** and **Chapter 6**.

Minimum Flows and Levels

Minimum Flows and Levels (MFL) are the point at which further withdrawals would cause significant harm to water resources. The LEC Plan is statutorily required to achieve MFLs that have been established for priority surface water bodies and aquifers or to develop a recovery and prevention strategy for those water bodies that are expected to exceed the proposed criteria. In the LEC Planning Area, MFLs have been proposed for three priority water bodies: Lake Okeechobee, the Everglades, and the Biscayne aquifer. The criteria defined in the *Minimum Flows and Levels for Lake Okeechobee, the Everglades, and the Biscayne Aquifer Final Draft Report* dated February 29, 2000, (SFWMD, 2000e) are described below and were incorporated into the modeling targets for the LEC Plan. In addition, MFLs are scheduled to be established for the Caloosahatchee River. These criteria were addressed in the CWMP and incorporated into the LEC Plan.

The ability to meet the proposed MFL criteria was determined by examining flow rates, water depth, duration of low water conditions, and return frequencies in Lake Okeechobee, coastal canals, and at various locations in Everglades’ peat soil and marl soil environments. The ability to achieve MFLs was assessed using the SFWMM for the 31-year simulation period. The subregional models were not used for such analyses because of the relatively short time period (two years) evaluated in these models and because they do not simulate Lake Okeechobee water levels; coastal canal stages, that are part of the Biscayne aquifer criteria; or many of the Everglades MFL gage locations.

Meeting MFL Criteria for Lake Okeechobee

Significant harm criteria developed for Lake Okeechobee were based on the relationship between water levels in the lake and the ability to a) protect the coastal aquifer against saltwater intrusion, b) supply water to Everglades National Park, c) provide littoral zone habitat for fish and wildlife, and d) ensure navigational and recreational access. Consideration was also given to the lake's function as a storage area for supplying water to adjacent areas such as the Everglades Agricultural Area (EAA), the Seminole Indian Tribe Reservervations, the Caloosahatchee and St. Lucie basins, and the LOSA.

Water Supply Planning MFL Criteria

Water levels should not fall below 11 ft NGVD for more than 80 days duration, more often than once every six years, on average (SFWMD, 2000e).

Meeting MFL Criteria for the Everglades

Technical relationships considered for developing MFL criteria for the Everglades included the effects of water levels on hydric soils and plant and wildlife communities, and frequency and severity of fires. Impacts associated with significant harm include increased peat oxidation, frequency of severe fires, soil subsidence, loss of aquatic refugia, loss of tree islands, and long-term changes in vegetation or wildlife habitat. The proposed minimum water level criteria for the Everglades were based on protecting the two dominant soil types found within the ecosystem as follows:

MFL Criteria for Peat-Forming Wetlands

Water levels within wetlands overlying organic peat soils within the WCAs, Rotenberger and Holey Land wildlife management areas, and Shark River Slough (Everglades National Park) shall not fall below ground surface for more than 30 days and shall not fall below 1.0 foot below ground for one day or more of that 30-day period, at specific return frequencies for different areas, as identified in **Table 44** later in this chapter.

MFL Criteria for Marl-Forming Wetlands

Water levels within marl-forming wetlands that are located east and west of Shark River Slough, the Rocky Glades, and Taylor Slough within Everglades National Park, shall not fall below ground surface for more than 90 days and shall not fall below 1.5 feet below ground for one day or more of that 90-day period at specific return frequencies for different areas, as identified in **Table 44** later in this chapter.

Meeting MFL Criteria for the Biscayne Aquifer

Criterion for the Biscayne aquifer were developed based on analysis of technical relationships among ground water levels and canal water levels, and the potential for saltwater intrusion. Harm occurs when the saltwater interface moves further inland than has occurred historically due to seasonal water level fluctuations, up to and including a 1-in-10 year drought. Significant harm occurs when saline ground water moves inland to an extent that it limits the ability of users to obtain fresh ground water in the amounts specified in their permits and will require several years for the freshwater source to recover.

The proposed criteria do not address the ground water base flows to Biscayne Bay or Florida Bay. Data are presently being collected to define MFLs for these water bodies.

Biscayne Aquifer Minimum Level

The term minimum level for the Biscayne aquifer refers to water levels associated with movement of the saltwater interface landward to the extent that ground water quality at the withdrawal point is insufficient to serve as a water supply source for a period of several years before recovering. For evaluation of model simulations, operational criteria are applied to the coastal canals that receive regional water. **Table 6** provides the minimum canal operational levels for eleven primary water management structures. To meet the operational criteria, the canal stage cannot fall below the levels for more than 180 days, and the average annual stage must be sufficient to allow levels and chloride concentrations in the aquifer to recover to levels that existed before a drought or discharge event occurred. See **Figure D-4** in **Appendix D** for an example of the model output for this performance measure.

Table 6. Minimum Canal Operation Levels of Coastal Canals.

Canal/Structure	Minimum Canal Operation Levels to Protect Against MFL Violations (ft NGVD)
C-51/S-155	7.80
C-16/S-41	7.80
C-15/S-40	7.80
Hillsboro/G-56	6.75
C-14/S-37B	6.50
C-13/S-36	4.00
North New River/G-54	3.50
C-9/S-29	2.00
C-6/S-26	2.50
C-4/S-25B	2.50
C-2/S-22	2.50

Meeting MFL Criteria for the Caloosahatchee Estuary

The proposed Caloosahatchee Estuary MFL criteria is based on maintaining freshwater base flows to the upper reaches of the Caloosahatchee Estuary, which will prevent excessive salinity levels in the estuary from causing significant harm to submerged aquatic vegetation and fish and invertebrate communities. Research data were used to relate freshwater flow rates to salinity distributions along the Caloosahatchee River and to correlate biologic community responses to varying salinity conditions. These relationships were established for submerged aquatic vegetation, fish, and invertebrates with major emphasis on the salinity requirements of the freshwater grass *Vallisneria* (commonly known as tape grass or eel grass). It was determined that the distribution and abundance of *Vallisneria* at a location 30 kilometers upstream of Shell Point is the best biological indicator for addressing freshwater flow needs for the restoration of the Caloosahatchee Estuary. The magnitude of die-off, combined with the frequencies of die-off events, and the resulting impact to fisheries resulting from the loss of *Vallisneria* habitat formed the basis of the proposed MFL criteria.

<u>Proposed Estuary Minimum Flow Criteria</u>

Low freshwater flows, when sustained, cause an increase in salinity, that result in die off of *Vallisneria* to less than 20 shoots per square meter as measured at a monitoring station located 30 kilometers upstream of Shell Point during the months of February through April. Significant harm to the Caloosahatchee Estuary is considered to occur when these freshwater grasses die back due to high salinity from low freshwater inflows for three years in succession. Harm to the Caloosahatchee Estuary is considered to occur when freshwater grasses die back due to high salinity from low freshwater inflows, for two consecutive years. The freshwater inflow needed to prevent harm or significant harm is an average of 300 cubic feet per second (cfs) per day at the S-79 structure during the months of February through April.

Environmental Resource Management Performance Indicators

Restoration Criteria from the Restudy

A number of resource protection criteria and performance measures that relate to hydropattern restoration of wetland systems and mimic the performance targets and evaluation criteria were used in the Restudy. The recommendations made within the Restudy will be refined and implemented in the Comprehensive Everglades Restoration Plan (CERP) currently being developed. District staff reviewed the Restudy natural area performance measures and indicators and incorporated them or revised versions of them into the LEC Plan as appropriate. Review of performance criteria showed that the model simulation for the 2020 with Restudy features completed by 2020 did not match the performance of model simulation for 2050 with CERP (Alternative D13R), because not all restoration components will be in place by 2020 (e.g., the Lake Belt projects are only about 50 percent complete by 2020). It was also recognized that the Alternative D13R simulation did not meet every target in 2050, hence the 2020 LEC Plan does not meet all of the performance measure targets identified in the CERP. Performance measures used in the LEC Plan were developed to evaluate the potential for the LEC Plan to achieve the following:

- Meet MFL criteria
- Promote protection and accretion of peat and marl soils
- Protect tree island communities
- Reestablish inundation patterns that will maintain Everglades sawgrass or ridge and slough marsh communities

In many areas, historic water conditions as predicted from results of the Natural System Model (NSM), were considered to be appropriate targets. For WCA-1 and WCA-3A, other targets were developed by the Restudy evaluation process that are more appropriate than NSM-like targets. Model results for each alternative were evaluated at the level of individual indicator regions (**Figure 25**). An indicator region is a group of model grid cells with similar vegetation and soil type.

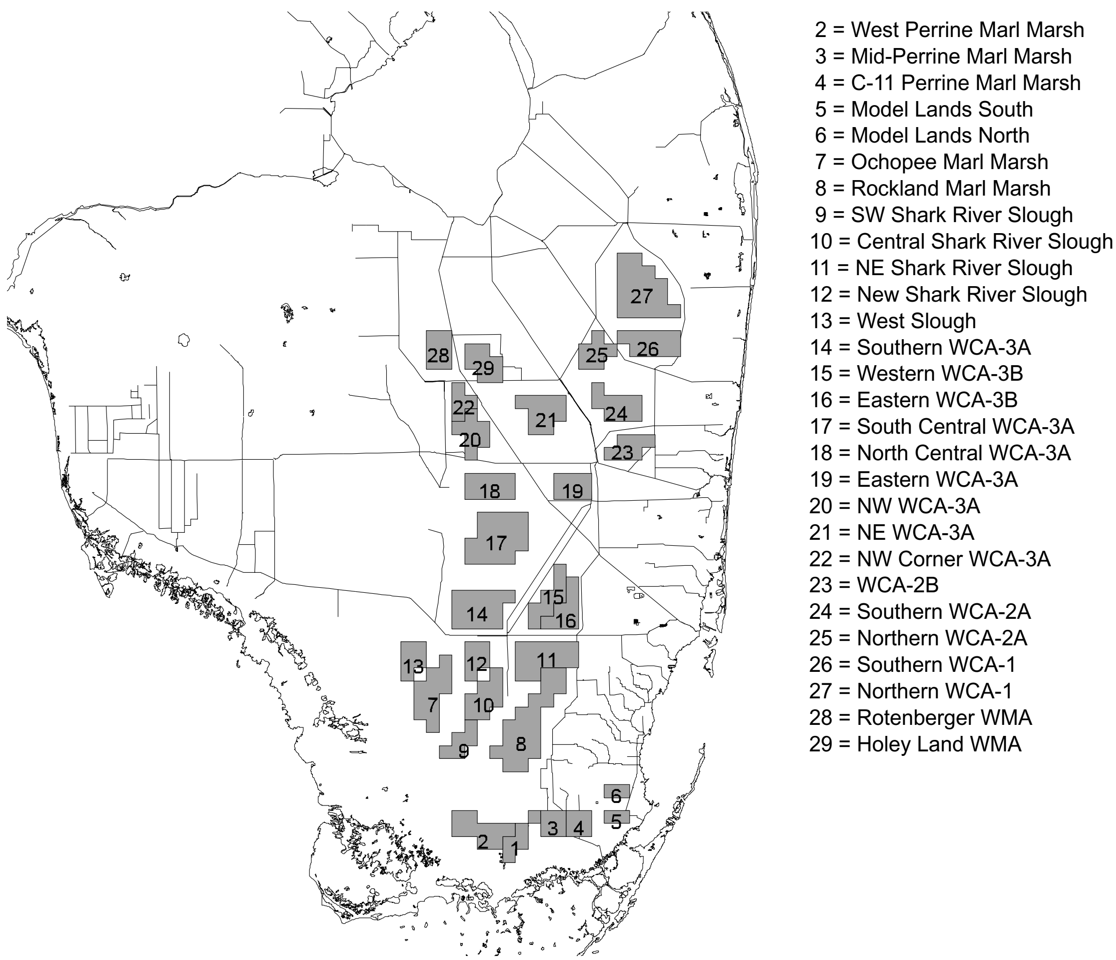

Figure 25. Locations of Indicator Regions Within the Everglades That Were Evaluated for the LEC Plan.

Performance of the model simulation was evaluated by considering the following performance measures, which are further described in **Appendix D**:

- The ability to meet MFL criteria for selected indicator regions
- The ability to meet NSM-defined patterns of surface water flooding inundation/duration where appropriate
- The number and duration of extreme high and low water events
- Interannual depth variation
- Temporal variation in mean weekly stage

Extreme High and Low Water Criteria

The following performance measures were initially developed by the Southern Everglades Restoration Alliance Natural Systems Team. These performance measures were used to evaluate SFWMM output and identify those areas of the Everglades that may suffer from either extreme high water or extreme low water events that impact the structure and function of existing wetland communities. These same performance measures were also used to screen proposed alternatives as outlined in the Restudy. In implementing the plan, it will be necessary to recognize that these performance measures, which are intended for comparison among model simulations, are not likely to translate directly into management criteria. Instead, further work will be needed to develop the information base from which to establish actual high and low water level targets for management purposes. It needs to be clearly recognized that the high and low water criteria contained in **Appendix D** were used primarily to identify extreme high or low water events that may impact Everglades tree islands, soils, plants, and/or wildlife communities. These criteria should not be interpreted as desired Everglades management objectives, but rather as screening tools to identify undesirable high or low water levels that should occur infrequently or be avoided.

Low Water Criterion. For extreme low water events, a criterion of 1.0 foot below ground surface was used for all indicator regions in the northern Everglades where peat-forming wetlands occur. A criterion of 1.5 feet below ground surface was applied to marl-forming soils located within the southern Everglades. These criteria are similar to the MFL water depth criteria proposed for the Everglades (SFWMD, 2000e).

High Water Criterion. For extreme high water events, a criterion of 2.5 feet above the ground surface was used in the northern Everglades (WCA-1, WCA-2, and WCA-3, except for northeastern WCA-3A [Indicator Region 21]). These regions are part of the historic Everglades predrainage ridge and slough landscape (McVoy, et al., in review), and include a variety of tree island types ranging from low stature peat islands that rise less than 1.0 foot above marsh ground elevation to tropical hardwood hammocks that exceed marsh ground elevation by more than 4.0 feet at their summits. The 2.5 feet criterion was based on several sources of information: 1) best professional judgement derived from federal and state agency scientists who have conducted research in the WCAs; 2) analysis of data collected from recent (1994 - 1995) high water events in

WCA-3A (Guerra, 1996); and 3) recent tree island and slough water level information collected from WCA-3A and WCA-3B by the Florida Wildlife Commission (FWC), formerly known as the Florida Fish and Wildlife Conservation Commission (FFWCC) (Heisler and Towles, 1999). For Indicator Region 21 in northeastern WCA-3A, a high water criterion of 2.0 feet was used, based on the rationale that this area of the Everglades was originally part of the remnant sawgrass plains and overall depth targets should be lower than for the ridge and slough landscape.

Based on the recommendations of FWC staff, a high water criterion of 1.5 feet was used for the Rotenberger WMA (Indicator Region 28), based on observations that tree islands in this area have reduced elevations as a result of peat loss from wildfires. For the Holey Land WMA (Indicator Region 29), a criterion of 1.5 feet was initially set, based on FWC observations that tree island wildlife refuges in the Holey Land WMA are eliminated once water depths exceed 1.5 feet. This criterion was later revised to 1.75 feet following further discussion with the FWC staff. As a result, a value of 1.5 feet appears in SFWMM output tables for the Holey Land WMA, although District staff actually used 1.75 feet as a minimum target for interpreting model output.

Interim Management Targets for Other Areas

For the St. Lucie River, the low flow, high flow, and estuary protection flow rates as defined by ongoing research and management studies, were used as performance measures. For Lake Worth Lagoon, only a high flow criterion has been defined. The performance measures for Biscayne Bay are composed of mean annual wet and dry season surface flows from various tributary canals. For the purposes of this study, the performance target for Biscayne Bay is that future flows delivered to the estuary should be similar to the flows provided in the 1995 Base Case. For western Florida Bay and Whitewater Bay, performance is based on surface flow at key gages and total flows delivered to the estuaries across selected transects located in central Shark River Slough. Flow targets are based on the ability to sustain the aquatic resources in the bays. These provisional criteria are subject to change as additional studies are completed and the District completes the actions needed to develop technical criteria, define MFLs, and implement associated rules that affect these estuaries (See **Recommendations 35** through **37** in **Chapter 6** and **Appendix J**).

Additional Performance Indicators

Water Supply Performance Indicators

A number of additional performance measures are routinely evaluated to determine the ability of the regional water supply system to provide water to individual utilities. These measures are used to identify specific areas where problems may occur, possible causes, and potential solutions. Measures used include the following (see **Appendix D** for more information):

- Daily hydrographs for each trigger cell in water restriction areas

- Monthly volumes of simulated water supply cutbacks for restriction areas
- Percentage of annual demand not met, by use type, for restriction areas
- Frequency and severity of water supply restrictions

Hydrologic Performance Indicators

A number of additional measures were used in the evaluation that did not have specific targets, but provided an overall indication of the relative behavior of each water supply alternative. Measures used include the following (see **Appendix D** for more information):

- Weekly stage hydrographs and stage-duration curves for selected indicator regions
- Normalized stage duration curves and hydrographs for selected indicator regions
- Hydroperiod distributions and hydroperiod matches
- Ground water flows, ground water heads, and overland flows

MODEL SIMULATIONS

Overview of Model Simulations

In the SFWMM and subregional ground water models, base case model simulations were conducted to determine current and future conditions of the LEC Planning Area. The 1995 estimated public water supply demand (1995 Base Case) and the 2020 projected public water supply demand (2020 Base Case) were used for these simulations. The 2020 base case assumed that a) water withdrawals for Public Water Supply reflect LEC utilities' preferred sources, b) future water users would withdraw water in the quantities indicated by public water suppliers, and c) existing agricultural and irrigation water users would use the same sources for both their current and future demands, unless information was made available indicating a change. The existing and projected uses of reclaimed water and Aquifer Storage and Recovery (ASR) systems (where information was available) were incorporated into the simulations.

In addition, the future base case assumes that other currently ongoing or proposed construction and planning efforts have been completed, including the Everglades Construction Project, Modified Water Deliveries to Everglades National Park, and the C-111 Basin project. Base case simulations represent the no action approach to water resource and supply development and are not a likely scenario.

Next, SFWMM and subregional ground water model simulations that include Restudy components were completed. It is anticipated that components of the Restudy will be substantially completed by 2020, with one notable exception: the Central and North Lake Belt storage areas. These projects are expected to be only 50 percent complete by 2020. These model simulations are referred to as 2020 with Restudy.

Additional simulations were also made to determine the cumulative effects of water supply withdrawals by utilities. In these simulations, referred to as LEC-1A, public water supplies and supplemental irrigation uses for golf courses, nurseries, agricultural crops, and landscaping were eliminated from the subregional ground water models. In the SFWMM simulations, only public water supply withdrawals were eliminated. ASR facilities associated with the Restudy remained active.

SFWMM simulations were also made to determine incremental benefits of proposed operational and structural changes over time, to simulate conditions that may exist in 2005, 2010, and 2015, as features of the Restudy, the LEC Plan, and other activities are completed. Additional improvements to water resource and water supply development projects that were identified in LEC-1 simulation were incorporated into the LEC-1 Revised simulation. An additional incremental modeling scenario, the 2005 SSM Scenario was also completed. The 2005 SSM Scenario was exactly the same as the 2005 incremental simulation, except that in the 2005 SSM Scenario Lake Okeechobee stages at which supply-side management restrictions are triggered (indicated by the supply-side management line) were lowered by 0.5 feet from the beginning of October through the end of May. The Lake Okeechobee target for May 31 was also reduced from 11.0 to 10.5 ft NGVD in the 2005 SSM Scenario.

Even though both types of models, the SFWMM and the subregional ground water models, simulate the LEC service areas, and its associated public water supply withdrawals, comparison of results between these two types of models is not appropriate due to differences in how features are simulated. Each model should be used to evaluate the areas and features for which it is best suited. The SFWMM, with its ability to simulate overland flow in wetlands, Lake Okeechobee, and the coastal canals, and its long simulated period of record, is best suited to analyze long-term regional trends in performance of those features. The ground water models with their small cells, stratification of the aquifer, and short time periods are adept at simulating small-scale features such as changes in wellfield locations, effects of ASR withdrawals, and ground water stages along the coast. The SFWMM with its large cells tends to lump these features and limit its sensitivity to small changes in assumptions and performance.

Both types of models, the regional SFWMM and subregional ground water models, initially performed five simulations: the 1995 Base Case, the 2020 Base Case, the 2020 with Restudy features, the LEC-1, and LEC-1A (no public water supply). Acronyms for these simulations are provided in **Table 7**. These same acronyms are used on the performance measure graphics compiled in **Appendix H**.

Table 7. Acronyms for SFWMM and Subregional Ground Water Model Base Case and Alternatives Simulations.

Simulation	SFWMM Acronym	Ground Water Model Simulation Acronym
1995 Base Case	95BSR	95Base
2020 Base Case	20BSR	20Base
2020 with Restudy	2020WR	20wres
LEC-1	LEC-1	LEC-1
LEC-1A	LEC-1A	LEC-1A

Assumptions for Base Cases and Alternatives

The regional and subregional models simulate the hydrology of South Florida on a daily basis including major components of the hydrologic cycle: rainfall, evapotranspiration, infiltration, ground water flow, canal flow, canal-ground water seepage, levee seepage, and ground water withdrawals. The SFWMM uses the climatic conditions from the 1965-1995 period, which includes both droughts and wet periods, while the subregional ground water models simulate the dry period from January 1988 to December 1990. The 1995 Base Case provides an understanding of the how the 1995 water management system with 1995 land use and demands responds to historic (1965-1995) climatic conditions. The 2020 Base Case provides information of how the system would respond to anticipated future operations and demands under the same historic climatic conditions with currently authorized restoration projects implemented, but without Restudy features. Comparison of the 1995 and 2020 base cases shows system performance with increased demands and inclusion of new projects and operating criteria.

The 2020 with Restudy simulations provide information on how the system performs with the implementation of the Restudy projects that would be completed by 2020 along with 2020 demands and operating criteria. The LEC-1 simulation provides information on how additional changes to water resource and water supply development projects may alter hydrologic performance.

The LEC-1A simulation was undertaken to understand the impact that permitted consumptive uses might have on the regional system. Using the subregional ground water models, effects on wetlands can be evaluated by comparing ground water stages in the LEC-1 simulation to the LEC-1A simulation. The manner in which the SFWMM and subregional ground water models simulate this varies. The SFWMM does not include public water withdrawals in Palm Beach, Broward, Miami-Dade, and Monroe counties, but includes agricultural and landscape irrigation demands. The subregional ground water models more closely mimic the permit review process by eliminating all consumptive uses (public water demands, agriculture, and landscape irrigation) within the models' boundaries from this simulation. In both simulations, ASR systems recommended in the Restudy operate as designed.

Primary Differences Between Base Cases and Alternatives

The major differences between the different types of model simulations are 1) changes in public water supply demands and locations of withdrawals, 2) inclusion of future projects and components, 3) modifications to Lake Okeechobee and WCA operation schedules, and 4) changes in land use between 1995 and 2020 and the resulting effect on agriculture and landscape irrigation demands. **Table 8** provides a summary of the the assumptions used in the 1995 and 2020 base cases, the 2020 with Restudy, and the LEC-1 simulations.

Table 8. Comparison of Assumptions in the 1995 and 2020 Base Cases, 2020 with Restudy, and LEC-1 Simulations.

Feature	1995 Base Case	2020 Base Case	2020 with Restudy	LEC-1	LEC-1A
Land Use for Urban and Agricultural Areas	Best available information for 1995	Projections based on county comprehensive plans; adjusted to reflect construction of Stormwater Treatment Areas (STAs)	Projections based on county comprehensive plans; adjusted to reflect construction of STAs and reservoirs as per Restudy	Projections based on county comprehensive plans; adjusted to reflect construction of STAs and reservoirs as per Restudy	Projections based on county comprehensive plans; adjusted to reflect construction of STAs and reservoirs as per Restudy
Vegetation Cover for Natural Areas	Best available information; generally reflect conditions between 1990-1995	Best available information; generally reflect conditions between 1990-1995	Best available information; generally reflect conditions between 1990-1995	Best available information; generally reflect conditions between 1990-1995	Best available information; generally reflect conditions between 1990-1995
LOSA Mean Annual Supplemental Irrigation Demands	170,000 ac-ft	191,000 ac-ft	239,000 ac-ft	227,000 ac-ft	227,000 ac-ft
EAA Mean Annual Supplemental Irrigation Demands	372,000 ac-ft	335,000 ac-ft	327,000 ac-ft	328,000 ac-ft	328,000 ac-ft
Lake Okeechobee Regulation Schedule	Run 25 Schedule	Water Supply and Environmental (WSE) Schedule	Modified Run 25 Schedule	Modified WSE Schedule	Modified WSE Schedule
Lake Okeechobee Supply-Side Management for LOSA	Yes	Yes	Yes	Yes	Yes
Caloosahatchee River Basin Demands (including municipal demands)	Demands based on historical records	25 percent increase over 1995 average annual demands	25 percent increase over 1995 average annual demands	25 percent increase over 1995 average annual demands	25 percent increase over 1995 average annual demands
Caloosahatchee Backpumping	N/A	N/A	As per Restudy	Reduced to zero as per CWMP	Reduced to zero as per CWMP
St. Lucie River Basin Demands	Demands based on historical records	Same as 1995	Same as 1995	Same as 1995	Same as 1995
C-44 Basin Storage Reservoir	N/A	N/A	As per Restudy	Modified as per Indian River Lagoon Feasibility[a] Study	Modified as per Indian River Lagoon Feasibility[a] Study
Brighton Seminole Indian Reservation Demands	28,500 ac-ft annual average; maximum 44,000 ac-ft/yr	28,500 ac-ft annual average; maximum 44,000 ac-ft/yr	52,000 ac-ft per year	28,500 ac-ft annual average; maximum 44,000 ac-ft/yr	28,500 ac-ft annual average; maximum 44,000 ac-ft/yr

Table 8. Comparison of Assumptions in the 1995 and 2020 Base Cases, 2020 with Restudy, and LEC-1 Simulations. (Continued)

Feature	1995 Base Case	2020 Base Case	2020 with Restudy	LEC-1	LEC-1A
STAs Associated with the EAA	No	Yes	Yes	Yes	Yes
EAA Runoff Reduction and Make-Up Water BMPs	No runoff reduction or make-up water delivered	No runoff reduction or make-up water delivered	20 percent EAA runoff reduction and make-up water delivered	No runoff reduction or make-up water delivered	No runoff reduction or make-up water delivered
Make-Up Water Associated with BMPs from Lake Okeechobee	No	No	No	No	No
WCA-1 Schedule	C&SF Interim Regulation Schedule	C&SF Interim Regulation Schedule	C&SF Interim Regulation Schedule	C&SF Interim Regulation Schedule	C&SF Interim Regulation Schedule
WCA-2 and WCA-3 Schedules	Current regulation schedule	Rain-driven operations and Modified Water Deliveries Project	Rain-driven operations	Rain-driven operations	Rain-driven operations
Everglades National Park Operations	Experimental Rainfall Delivery Plan via S-12s and S-333	As per Modified Water Deliveries Project	As per Restudy	As per Restudy	As per Restudy
LECSAs Population for Utilities	4,755,776 persons	6,951,998 persons as per LEC utility survey	6,951,998 persons as per LEC utility survey	6,951,998 persons, as per LEC utility survey	6,951,998 persons, as per LEC utility survey
LECSAs Public Water Supply Demands on Surficial Aquifer System and Surface Water	Actual 1995 demands: 286,429 MGY (784.1 MGD)	Projected demands based on LEC utility survey: 443,411 MGY (1,214.8 MGD)	Projected demands based on LEC utility survey: 443,411 MGY (1,214.8 MGD)	Projected demands based on LEC utility survey: 443,411 MGY (1,214.8 MGD)	No public water supply demand
LECSAs Public Water Supply Wellfield Distribution	Actual 1995 locations	Utility preferred wellfield locations, as per LEC utility survey	As per Restudy	Modifications to eleven utilities preferred wellfield locations as per LEC utility survey	Not applicable
LECSAs Water Shortage Policy	Yes	Yes	Yes	Yes	Yes
LEC Irrigation Demands on Surficial Aquifer System	Based on 1995 land use and climatic variation	Based on projected 2020 land use and climatic variation	Based on projected 2020 land use and climatic variation	Based on projected 2020 land use and climatic variation	Based on projected 2020 land use and climatic variation
Operational Adjustments to Meet MFLs for Biscayne Aquifer	No	Canal operation criteria (**Table 23**)	Canal operation criteria (**Table 23**)	Canal operation criteria (**Table 23**)	Canal operation criteria (**Table 23**)
L-8 Project[b]	No	Yes, as per the LEC Interim Plan	Yes, as per Restudy	Yes, as per Restudy	Yes, as per Restudy
Northern Broward County Secondary Canal Network[b]	No	Yes, as per the LEC Interim Plan	Yes, as per Restudy	Yes, as per Restudy	Yes, as per Restudy
Miami-Dade Utility ASR[b]	No	150 MGD	150 MGD	75 MGD	75 MGD
Miami-Dade County Reuse[b]	No	No	100 MGD at west facility	50 MGD at west facility	50 MGD at west facility

a. USACE, 1996
b. Ongoing project from the *Interim Plan for Lower East Coast Regional Water Supply* (SFWMD, 1998b)

Public Water Supply Demands

The simulations used two demand sets (allocation sets) for public water supply in the LEC Planning Area: 1995 and 2020. The 1995 demands represent estimated average annual demands for that year (286,429 MGY). The 2020 demands (443,411 MGY) are a projection of future demands provided by public water suppliers to District staff in January 1999. **Appendix B** contains a detailed discussion of estimated and projected public water supply demands. These projected 2020 average annual demands are used in the 2020 simulations (2020 Base Case, 2020 with Restudy, and LEC-1).

The District also developed 2020 public water supply projections in the *Districtwide Water Supply Assessment* (DWSA) (SFWMD, 1998c). The DWSA projected total demands in the LEC Planning Area as 389,440 MGY. The utility projections anticipated a 14 percent higher demand in 2020 than the estimates in the DWSA. The average public water supply per capita rate for the LECSAs fairly constant for the utility (176 gallons per capita daily [gpcd]) and District projections (179 gpcd). Most utilities continued their current per capita water consumption rate, while some anticipate a lower per capita rate coupled with higher population projections or vice versa. These two projections were considered to represent low and high values that bracket a range of future projections. Conservation of water may increase in the future as a greater percentage of houses use low flow fixtures, have smaller yards, or depend on reuse for irrigation. Thus, the lower projection may prove accurate. On the other hand, the population may grow at or above the rates the utilities anticipate and the higher demand projections may be reached. Using the higher demand in the LEC Plan is the more conservative approach. In this case, water resource development projects are needed immediately to meet environmental demands. The population and demand projections will be reassessed for each utility during the CUP process and future updates of LEC Plan.

The physical locations of public water withdrawals also vary between the 1995 and 2020 simulations (see **Appendix B** for maps). In the 1995 Base Case, withdrawals are similar to historic conditions in 1995, i.e., only wells existing in 1995 and the corresponding wellfield distribution were included. In the future 2020 model simulations, locations of withdrawals include new wells built since 1995 and proposed locations provided by public water supply utilities to the District in January 1999. Data provided by the utilities consist of their initial or preferred locations and the resulting distribution of withdrawals among the wellfields. To view how the SFWMM simulates these demands at the utilities preferred locations, refer to the Spatial Distribution of Public Water Supply Demands section in **Appendix B**. Some utilities proposed many new wells to meet future demands while others foresee constructing no new wells by 2020.

The physical locations of public water withdrawals also vary between the 2020 with Restudy and the LEC-1 model simulations. In the 2020 with Restudy, withdrawal locations are similar to those used in the Restudy's Alternate D13R simulation (USACE and SFWMD, 1999). The Restudy relied upon the SFWMM and its four square mile grid to simulate LEC urbanized areas. The primary method to alleviate low ground water levels along the coast and anticipate future well locations was to move public water supply demands inland. The large grid cells do not enable the degree of refinement of well distributions or locations that is possible with the subregional ground water models. In the LEC-1 simulations, most withdrawal locations are the same as in the 2020 Base Case. The LEC-1 incorporates the utility preferred locations for future wells. In addition, eleven utilities had at least a portion, if not all, of their withdrawals relocated to existing wellfield locations further inland to reduce the threat of saltwater intrusion and/or reduce the frequency water supply restrictions. These locations are assumed only for modeling and planning purposes and are not meant to imply that permits are obtainable.

Agricultural Water Supply Demands

In the SFWMM, the 1995 demand level represents estimated agricultural water demands for acreage that was permitted by the District through the end of 1995. For irrigation uses, demands for permitted acreage were calculated based on crop type and simulated rainfall events. The 2020 demand level is based on projected 2020 agricultural acreage, as indicated in on local county comprehensive plans. All irrigation demands were calculated using the modified Blaney-Criddle method for each rainfall condition. A detailed discussion of this method can be found in the District's *Management of Water Use Permitting Information Manual, Volume III* (SFWMD, 1997d). Blaney-Criddle is currently used to estimate supplemental crop requirements in the District's CUP program. Details of demand assumptions are described in **Appendix B.**

In the base cases and alternatives, agricultural demands in the Caloosahatchee Basin were projected using the same method applied in the Restudy. The projected demands in 2020 are 25 percent greater than in 1995. While in the Restudy the 2050 projection was 40 percent greater than 1995. Refer to the CWMP for more information regarding the assumptions that were used in the integrated surface and ground water model.

Inclusion of Restudy Components

The second primary difference between the base case and alternative simulations is inclusion of future projects and components. The 2020 with Restudy simulation only includes those Restudy components that are expected to be completed by 2020. According to the Restudy Implementation Plan (USACE and SFWMD, 1999), all components are to be completed by 2020 except that only half of the total volume of the North and Central Lake Belt projects will be available. **Table 9** identifies the Restudy components included in the 2020 with Restudy simulation performed by the SFWMM and subregional ground water models.

Table 9. Components Included in the 2020 with Restudy Model Simulations.

Component Name	Regional SFWMM v3.7	Subregional Ground Water Models
Indian River Lagoon		
C-44 Basin Storage Reservoir[a]	X	
C-23/C-24/Northfork and Southfork Reservoirs[a]	X	
Lake Okeechobee Headwaters Storage		
Taylor Creek/Nubbin Slough Storage Reservoir and STA[a]	X	
North of Lake Okeechobee Storage Reservoir[a]	X	
Lake Okeechobee		
Lake Okeechobee ASR[a]	X	
Caloosahatchee River Basin		
C-43 Basin Storage Reservoir with ASR[a]	X	
Caloosahatchee Backpumping with STA[ab]	X	
Everglades Agriculture Area		
EAA Storage Reservoirs[a]	X	
Lower East Coast		
LEC Utility Water Conservation		
Broward County Secondary Canal System	X	X
C-4 Control Structure	X	X
C-111N Spreader Canal	X	X
Water Preserve Area Components		
C-9 STA/Impoundment	X	X
Western C-11 Diversion Impoundment and Canal	X	X
Dade-Broward Levee/Pennsuco Wetlands	X	X
Hillsboro (Site 1) Impoundment and ASR	X	X
Acme Basin B Discharge	X	X
Protect and Enhance Existing Wetland Systems along Loxahatchee National Wildlife Refuge including the Strazulla Tract	X	X
Pal-Mar and J.W. Corbett WMA Hydropattern Restoration	X	X
C-17 Backpumping and Treatment	X	X
C-51 Backpumping and Treatment	X	X
Bird Drive Recharge Area	X	X
Levee Seepage Management		
L-31N Levee Improvements for Seepage Management	X	X
WCA-3A and WCA-3B Seepage Management	X	X
Construction of S-356 Structures and Relocation of a Portion of the L-31N Borrow Canal	X	X
C-111 Operational Modifications[c]	X	X
Storage with ASR Components		
L-8 Project	X	X
C-51 and Southern L-8 Reservoir	X	X
C-51 Regional Ground Water ASR	X	X
Palm Beach County Agricultural Reserve Reservoir and ASR	X	X

Table 9. Components Included in the 2020 with Restudy Model Simulations. (Continued)

Component Name	Regional SFWMM v3.7	Subregional Ground Water Models
Lake Belt Storage and Conveyance		
Central Lake Belt Storage Area, Phase 1[d]	X	X
Divert flows from Central Lake Belt Storage Area to WCA-3B	X	X
Divert Flows from WCA-3 to Central Lake Belt Storage Area	X	X
Divert Flows from WCA-2 to Central Lake Belt Storage Area	X	X
North Lake Belt Storage Area, Phase 1[d]	X	X
Water Conservation Areas and Everglades National Park		
Revised Holey Land WMA Operation Plan[a]	X	
Revised Rotenberger WMA Operation Plan[a]	X	
Loxahatchee National Wildlife Refuge Internal Structures	X	X
Reroute Miami-Dade Water Supply Deliveries	X	X
Additional S-345 Structures	X	X
Decompartmentalize WCA-3	X	X
G-404 Pump Station Modification	X	X
Biscayne Bay		
Biscayne Bay Coastal Wetlands	X	X
West Miami-Dade County Reuse	X	X
South Miami-Dade County Reuse	X	X
Western Basin		
Miccosukee Tribe Water Management Plan[a]	X	
Flow to Northwest and Central WCA-3A[a]	X	
Big Cypress/L-28 Interceptor Modifications[a]	X	
Seminole Tribe Big Cypress Basin Water Conservation Plan[a]		
Stand Alone Other Project Elements (OPEs)		
Lake Okeechobee Watershed Water Quality Treatment Facilities[e]		
Lake Okeechobee Tributary Sediment Dredging[e]		
Lake Worth Lagoon Restoration[e]		
Pineland and Hardwood Hammocks Restoration[e]		
Melaleuca Eradication Project and Other Exotics[e]		
Florida Keys Tidal Restoration[e]		
Winsburg Farms Wetlands[e]		

a. Outside of the subregional ground water models' boundaries
b. Modeled in the CWMP
c. The C-111 Operational Modifications are part of the Modification to South Dade Conveyance System in Southern Portion of L-31N and C-111 Canals component.
d. 50 percent completed by 2021
e. Cannot be simulated with these types of hydrologic models

Lake Okeechobee and Water Conservation Area Schedules

Changes in the Lake Okeechobee and WCAs schedules can have significant impacts on how outflows from the lake are managed to meet multiple purposes. The LEC 1995 Base Case relies upon the current U.S. Army Corps of Engineers (USACE) approved schedules to manage water in the lake and WCAs, while the all future simulations (2020 Base Case, LEC-1, and LEC-1A) anticipates implementation of the Water Supply and Environmental (WSE) schedule on the lake and rain-driven schedules for the WCAs and Everglades National Park. The 2020 with Restudy simulation follows this precedent, relies upon rain-driven schedules for the WCAs, but uses a modified Run 25 schedule for the lake. When comparing results, the changes in operations and schedules have significant effects on the ability to meet performance targets.

Current and Future Land Use

One of the primary model assumptions is how land is used, whether it is covered with houses and roads or is a natural wetland. The type of land use applied in the model most directly affects how the models handle evapotranspiration and overland flow or recharge. Three land use databases were developed for the LEC Plan analysis: 1) 1995 land use, which is based on interpretation of aerial surveys; 2) 2020 land use, which is an interpretation of the county comprehensive land use plans; and 3) 2020 with Restudy land use, which is the same as the 2020 land use except that it has been modified to reflect construction of the Restudy features.

Incremental Simulations

The purpose of this analysis was to understand how the system performs in the interim period between now and 2020. Incremental years, 2005, 2010, and 2015, were selected to provide snapshots of how the system performs with partial completion of the Restudy projects and how the ability to meet the 1-in-10 year level of certainty criteria improves over time. Also, improvements to the performance of LEC-1 were incorporated into the LEC-1 Revised, which is the now the new 2020 end point for comparing simulations.

This analysis consisted of identifying the components that were scheduled to be complete and fully operational by the end of each year selected (**Table 10**). These components were then modeled to evaluate whether the partial or sequential completion of projects would cause ecological or water supply conditions that are worse than the 1995 Base Case or would result in progressive improvement in performance during the interim period. The modeling analysis and evaluation of the components utilized the same performance measures as the base cases and LEC-1 analyses. This analysis was used to identify problem areas and confirm that the original implementation schedule developed for Restudy was sequenced in a logical order that furthered the goals and objectives of the LEC Plan.

Table 10. Implementation Schedule for Restudy Components in Five-Year Increments.

Component Name	2005	2010	2015	LEC-1 Revised
Indian River Lagoon				
C-44 Basin Storage Reservoir		X	X	X
C-23/C-24/Northfork and Southfork Reservoirs		X	X	X
Lake Okeechobee Headwaters Storage				
Taylor Creek/Nubbin Slough Storage Reservoir and STA		X	X	X
North of Lake Okeechobee Storage Reservoir			X	X
Lake Okeechobee				
Lake Okeechobee ASR			X (50%)	X
Caloosahatchee River Basin				
C-43 Basin Storage Reservoir		X	X	X
C-43 Basin ASR			X	X
Caloosahatchee Backpumping with STA				
Everglades Agriculture Area				
EAA Storage Reservoirs, Phase 1		X	X	X
EAA Storage Reservoirs, Phase 2			X	X
Lower East Coast				
LEC Utility Water Conservation				
Broward County Secondary Canal System		X	X	X
C-4 Control Structure	X	X	X	X
C-111N Spreader Canal		X	X	X
Water Preserve Area Components				
C-9 STA/Impoundment		X	X	X
Western C-11 Diversion Impoundment and Canal		X	X	X
Dade-Broward Levee/Pennsuco Wetlands		X	X	X
Hillsboro (Site 1) Impoundment		X	X	X
Hillsboro (Site 1) Impoundment ASR			X	X
Acme Basin B Discharge		X	X	X
Protect and Enhance Existing Wetland Systems along Loxahatchee National Wildlife Refuge including the Strazulla Tract		X	X	X
Pal-Mar and J.W. Corbett WMA Hydropattern Restoration		X	X	X
C-17 Backpumping and Treatment		X	X	X
C-51 Backpumping and Treatment		X	X	X
Bird Drive Recharge Area			X	X
Levee Seepage Management				
L-31N Levee Improvements for Seepage Management		X	X	X
WCA-3A and WCA-3B Seepage Management		X	X	X
Construction of S-356 Structures and Relocation of a Portion of the L-31N Borrow Canal		X	X	X
C-111 Operational Modifications[a]	X	X	X	X
Storage with ASR Components				
L-8 Project			X	X
C-51 and Southern L-8 Reservoir			X	X

Table 10. Implementation Schedule for Restudy Components in Five-Year Increments.

Component Name	2005	2010	2015	LEC-1 Revised
C-51 Regional Ground Water ASR			X	X
Palm Beach County Agricultural Reserve Reservoir and ASR			X	X
Lake Belt Storage and Conveyance				
Central Lake Belt Storage Area, Phase 1				X
Divert flows from Central Lake Belt Storage Area to WCA-3B			X	X
Divert Flows from WCA-3 to Central Lake Belt Storage Area				X
Divert Flows from WCA-2 to Central Lake Belt Storage Area				X
North Lake Belt Storage Area, Phase 1				X
Water Conservation Areas and Everglades National Park				
Revised Holey Land WMA Operation Plan		X	X	X
Revised Rotenberger WMA Operation Plan	X	X	X	X
Loxahatchee National Wildlife Refuge Internal Structures	X	X	X	X
Reroute Miami-Dade Water Supply Deliveries		X	X	X
Additional S-345 Structures		X	X	X
Decompartmentalize WCA-3		X	X	X
G-404 Pump Station Modification		X	X	X
Biscayne Bay				
Biscayne Bay Coastal Wetlands				X
West Miami-Dade County Reuse				X (50%)
South Miami-Dade County Reuse				X
Western Basin				
Miccosukee Tribe Water Management Plan		X	X	X
Flow to Northwest and Central WCA-3A		X	X	X
Big Cypress/L-28 Interceptor Modifications				X
Seminole Tribe Big Cypress Basin Water Conservation Plan		X	X	X
Stand Alone OPEs				
Lake Okeechobee Watershed Water Quality Treatment Facilities				
Lake Okeechobee Tributary Sediment Dredging				
Lake Worth Lagoon Restoration				
Pineland and Hardwood Hammocks Restoration				
Melaleuca Eradication Project and Other Exotics				
Florida Keys Tidal Restoration				
Winsburg Farms Wetlands				

a. The C-111 Operational Modifications are part of the Modification to South Dade Conveyance System in Southern Portion of L-31N and C-111 Canals component.

Assumptions for Incremental Simulations

Incremental simulations were performed with the SFWMM to understand how the system behaves as features of the plan are constructed or implemented. The 1995 Base Case and LEC-1 provide beginning and end points to evaluate progress over time as components are implemented. The beginning and end points were revised to make comparisons to the incremental simulations valid, i.e. incorporate similar model assumptions so the only variables were the Restudy projects themselves. These simulations are referred to as the 1995 Revised Base Case and the LEC-1 Revised, respectively. **Table 11** references the acronyms used in the model results graphics found in **Appendix H**. Agricultural, urban, and environmental demands increased over time as demands and water supplies increased. A summary of the modeling assumptions for the incremental simulations can be found in **Table 12**.

Table 11. Acronyms for SFWMM Incremental Simulations.

Simulation	Acronym
1995 Revised Base Case	95BSRR
2005	2005R
2005 SSM Scenario	2005 SSM
2010	2010R
2015	2015R
LEC-1 Revised	LEC-1R or 2020R

Assumptions for 2005 SSM Scenario

A 2005 Supply-Side Scenario (SSM) was also simulated with the SFWMM as part of the incremental simulation analysis. The purpose of this scenario was to determine how sensitive the modifications to the regional system were to Lake Okeechobee's operations and its ability to meet water supply demands. In the 2005 SSM Scenario, the Lake Okeechobee supply-side management criteria were modified. Other alternatives to achieve this goal will also be considered in solution development.

The Supply-Side Management restrictions were designed to be conservative and retain water in the regional system to meet unforeseen demands later in the drought or dry season. The conservative approach may be too restrictive for future conditions, especially considering additional demands placed on the lake since the supply-side management criteria was developed. By 2005, several new demands are placed on Lake Okeechobee, but no regional storage features are available to meet some of these new demands. The increased demands in 2005 include the Everglades Construction Project, the rain-driven schedules for the WCAs, and Caloosahatchee Basin and lower Lake Istokpoga supplemental irrigation demands. To meet the existing and future demands on Lake Okeechobee, the stage that triggers supply-side management was lowered by approximately one-half of a foot. The end of dry season (May 31) stage target was also reduced from 11.0 to 10.5 ft NGVD.

Table 12. Comparison of Assumptions for Incremental Model Simulations by the SFWMM.

Feature	1995 Revised Base Case	2005	2010	2015	LEC-1 Revised
Land Use for Urban and Agricultural Areas	Best available information for 1995	Best available information for 1995; adjusted to reflect construction of STAs	2020 projections based on county comprehensive plans; adjusted to reflect construction of STAs and appropriate components in Restudy	2020 projections based on county comprehensive plans; adjusted to reflect construction of STAs and appropriate components in Restudy	2020 projections based on county comprehensive plans; adjusted to reflect construction of STAs and appropriate components in Restudy
Vegetation Cover for Natural Areas	Same as 1995; best available information; generally reflects conditions between 1990-1995	Same as 1995; best available information; generally reflects conditions between 1990-1995	Same as 1995; best available information; generally reflects conditions between 1990-1995	Same as 1995; best available information; generally reflects conditions between 1990-1995	Same as 1995; best available information; generally reflects conditions between 1990-1995
LOSA Mean Annual Supplemental Irrigation Demands	217,000 ac-ft	234,000[a] ac-ft	260,000 ac-ft	225,000 ac-ft	229,000 ac-ft
EAA Mean Annual Supplemental Irrigation Demands	371,000 ac-ft	351,000 ac-ft	332,000 ac-ft	327,000 ac-ft	333,000 ac-ft
Lake Okeechobee Regulation Schedule	WSE schedule	WSE schedule	Modified WSE schedule[b]	Modified WSE schedule[b]	Modified WSE schedule[b]
Lake Okeechobee Supply-Side Management for LOSA	Current schedule	Current schedule	Modified schedule[c]	Modified schedule[c]	Modified schedule[c]
Caloosahatchee River Basin Demands (including municipal demands and supplies)	Demands for 1995 estimated using AFSIRS method per CWMP	Demands for 2005 estimated using AFSIRS method per CWMP	Demands for 2010 estimated using AFSIRS method per CWMP	Supplies limited to Restudy deliveries of approx. 29,000 ac-ft/ yr at S-77	Supplies limited to Restudy deliveries of approx. 29,000 ac-ft/ yr at S-77
Caloosahatchee Backpumping	Not applicable	Not applicable	Set to zero as per CWMP	Set to zero as per CWMP	Set to zero as per CWMP
C-44 Basin Storage Reservoir	Not constructed	Not constructed	Constructed and operated as per Indian River Lagoon Feasibility Study[d]	Constructed and operated as per Indian River Lagoon Feasibility Study[d]	Constructed and operated as per Indian River Lagoon Feasibility Study[d]
Brighton Seminole Indian Reservation Demands	28,500 ac-ft annual average; maximum 44,000 ac-ft/yr	28,500 ac-ft annual average; maximum 44,000 ac-ft/yr	28,500 ac-ft annual average; maximum 44,000 ac-ft/yr	28,500 ac-ft annual average; maximum 44,000 ac-ft/yr	28,500 ac-ft annual average; maximum 44,000 ac-ft/yr
STAs Associated with the EAA	Yes	Yes	Yes	Yes	Yes
EAA Runoff Reduction and BMP Make-Up Water	No runoff reduction or make-up water delivered	No runoff reduction or make-up water delivered	No runoff reduction or make-up water delivered	No runoff reduction or make-up water delivered	No runoff reduction or make-up water delivered
Make-Up Water Associated with Best Management Practices (BMPs) from Lake Okeechobee	No	No	No	No	No
EAA Storage Reservoirs	Not constructed	Not constructed	Redirect Miami, North New River, and Hillsboro basins' runoff to EAA Storage Reservoirs; 30,000 acres for EAA water supply and 30,000 acres for environmental water supply; used to meet demand in all major EAA basins (including West Palm Beach)	Redirect Miami, North New River, and Hillsboro basins' runoff to EAA Storage Reservoirs; 30,000 acres for EAA water supply and 30,000 acres for environmental water supply; used to meet demand in all major EAA basins (including West Palm Beach)	Redirect Miami, North New River, and Hillsboro basins' runoff to EAA Storage Reservoirs; 30,000 acres for EAA water supply and 30,000 acres for environmental water supply; used to meet demand in all major EAA basins (including West Palm Beach)

Table 12. Comparison of Assumptions for Incremental Model Simulations by the SFWMM. (Continued)

Feature	1995 Revised Base Case	2005	2010	2015	LEC-1 Revised
WCA-1 Schedule	Interim regulation schedule	Interim regulation schedule	Interim regulation schedule	Interim regulation schedule	Interim regulation schedule
WCA-2A Schedule	Current regulation schedule	Current regulation schedule	Rain-driven schedule	Rain-driven schedule	Rain-driven schedule
WCA-2B, WCA-3A, and WCA-3B Schedules	Current regulation schedule	Rain-driven schedule	Rain-driven schedule	Rain-driven schedule	Rain-driven schedule
Everglades National Park Operations	Experimental Rainfall Delivery Plan via S-12s and S-333 structures	As per Modified Water Deliveries Project GDM w/o tailgated constraints on L-29	As per MWD Project GDM w/o tailwater constraints on L-29	As per Restudy	As per Restudy
LECSA Population	4,755,776 persons	5,304,831 persons	5,853,886 persons	6,402,941 persons	6,951,998 persons, as per LEC utility survey
LECSAs Public Water Supply Demands on Surficial Aquifer System and Surface Water	Actual 1995 demands: 286,429 MGY (784.10 MGD)	325,464 MGY (892.5 MGD)	364,927 MGY (999 MGD)	403,948 MGY (1,106.5 MGD)	Projected demands based on LEC utility survey: 443,411 MGY (1,214.8 MGD)
LECSAs Public Water Supply Wellfield Distribution	Actual 1995 locations	Modifications to eleven utilities' preferred wellfield locations (based on LEC utility survey)	Modifications to eleven utilities' preferred wellfield locations (based on LEC utility survey)	Modifications to eleven utilities' preferred wellfield locations (based on LEC utility survey)	Modifications to eleven utilities' preferred wellfield locations (based on LEC utility survey)
LECSAs Water Shortage Policy	Yes	Yes	Yes	Yes	Yes
LEC Irrigation Demands on Surficial Aquifer System	Based on land use and climatic variation	Based on projected 1995 land use and climatic variation	Same as LEC-1 Revised	Same as LEC-1 Revised	Based on projected 2020 land use and climatic variation
Operational Adjustments to Meet MFLs for Biscayne Aquifer	No	Canal operation criteria (**Table 6**)	Canal operation criteria (**Table 6**)	Canal operation criteria (**Table 6**)	Canal operation criteria (**Table 6**)
L-8 Project	Not constructed	Not constructed	Not constructed	As per Restudy	As per Restudy
Broward County Secondary Canal System	Not constructed	Partial, the northern portion only	As per Restudy	As per Restudy	As per Restudy
Miami-Dade Utility ASR	Not constructed	25 MGD	50 MGD	75 MGD	75 MGD
Miami-Dade County Reuse	Not constructed	0 MGD	0 MGD	0 MGD	50 MGD west facility; 131 MGD south facility
Optimization of Regional ASR	Not applicable	Not applicable	Not applicable	Excess water from C-51 ASR and West Palm Beach Catchment Area ASR sent to meet EAA demands	Excess water from C-51 ASR and West Palm Beach Catchment Area ASR sent to meet EAA demands
Lake Istopokga Demand and Runoff	12,000 ac-ft average annual demands; 6,000 ac-ft average annual runoff	12,000 ac-ft average annual demands; 6,000 ac-ft average annual runoff	12,000 ac-ft average annual demands; 6,000 ac-ft average annual runoff	12,000 ac-ft average annual demands; 6,000 ac-ft average annual runoff	12,000 ac-ft average annual demands; 6,000 ac-ft average annual runoff

a. Accounts for reduction due to construction of STAs and reservoirs
b. WSE schedule was modified to incorporate operations associated with the Lake Okeechobee ASR, the EAA Storage Reservoirs, and the North of Lake Okeechobee Storage Reservoir
c. Modified supply-side schedule management accounts for storage available in reservoirs around Lake Okeechobee
d. USACE, 1996

Additional Assumptions of Base Cases, Alternatives, and Incremental Simulations

Modifications to assumptions in the SFWMM were made to improve performance and meet hydrologic targets. Additional assumptions were also made to update information included in the SFWMM to reflect best available information. These changes are discussed below. To identify which simulations incorporated these assumptions, refer to **Tables 8** and **12**.

Best Management Practice Make-Up Water

In previous analyses, it had been assumed that the implementation of Best Management Practices (BMPs) in the EAA would reduce the volume of runoff from the EAA to the Everglades by 20 percent. According to the Everglades Forever Act, and subsequent SFWMD rules, this reduction of flow must be offset by additional releases from Lake Okeechobee. Now that the BMPs have been in place for five full years, actual runoff data have been analyzed to quantify the change in runoff attributable to the BMP Program. An extensive review of the available data conducted under the auspices of the EAA Environmental Protection District indicates that no measurable reduction in runoff has occurred due to implementation of BMPs. Therefore, for the purposes of computer modeling to support the LEC Plan, no reduction in runoff and, consequently, no make-up water deliveries were simulated. Ongoing rulemaking by the District on the make-up water requirements will assess the quantity of runoff from the EAA, which will then be incorporated into future regional analyses.

Brighton Seminole Indian Reservation Demands

The Seminole Tribe has an existing compact[1] with the SFWMD for water deliveries from Lake Okeechobee to meet supplemental irrigation demands of the Brighton Reservation. In the LEC Plan, the demand varies seasonally and annually with a maximum annual demand of 44,000 ac-ft and an average annual demand of 28,500 ac-ft. These demands differ from what was assumed during the Restudy.

Miccosukee Tribe of Indians Demands

The demands of the Miccosukee Tribe of Indians assumed in the regional water supply planning process are based on representations of the Miccosukee Tribe as to their water needs for the next 20 years. No attempt was made in this planning process to determine whether the Miccosukee Tribe of Indians has any federal legal right to the requested water quantities. As a result, the findings and the conclusions of the LEC Plan are not intended to create or alter any rights to water the Miccosukee Tribe may currently have or intend to perfect in the future under federal or state law. The Governing Board encourages the Miccosukee Tribe to engage in negotiations with the District and the State

1. Water Rights Compact in 1987 which was enacted by Pub. L. No. 100-228, 101 Stat. 1556, and Chapter 87-292, Laws of Florida, and codified in Section 285.165, Florida Administrative Code (F.A.C.)

of Florida to achieve a mechanism for recognition of tribal water rights. The District will participate in any processes conducted to achieve this goal.

Caloosahatchee Basin Demands

The Caloosahatchee Basin demand projections used in the 1995 and 2020 base cases, 2020 with Restudy, and LEC-1 simulations were derived in the same fashion as those assumed in the Restudy modeling. The 1995 Base Case is based on historical demands and the 2020 demand projection is 25 percent greater than in 1995. The Restudy assumed a 40 percent increase in demands in 2050 compared to 1995. The future supplemental irrigation demands are met from Lake Okeechobee in the 2020 Base Case. In the 2020 with Restudy and LEC-1 simulations, the future demands are met partially from the C-43 Reservoir and ASR facilities.

The demand projections that were developed for the CWMP form the basis for the evaluation of demands in the Caloosahatchee Basin in the incremental simulations performed for the LEC Plan. These demands were met from Lake Okeechobee in the 1995 Revised Base Case and the 2005 and 2010 incremental simulations. In the 2015 and LEC-1 Revised regional model simulations, the demands were met from the C-43 Reservoir and ASR system and a portion was met from Lake Okeechobee. In the incremental simulations, the demands in 2010, 2015, and LEC-1 Revised are capped at the same average annual volume that can be provided in the 2020 with Restudy model simulation. In other words, the demands in the incremental simulations use the revised demands as projected by the CWMP, but they are met from within the Caloosahatchee Basin once the C-43 Reservoir is constructed.

Caloosahatchee Basin Backpumping to Lake Okeechobee

One major difference between the 2020 with Restudy and LEC-1 model simulations is that in the LEC-1 simulation, no backpumping occurs from the Caloosahatchee Basin. This source of water to the lake is no longer considered available. This is also true for all incremental model simulations. This assumption will need further evaluation as the demand and runoff estimates developed by AFSIRS are part of the Restoration, Coordination, and Verification (RECOVER) process for the CERP.

Minimum Flows and Levels for the Biscayne Aquifer

The minimum water levels for coastal canals that are needed to protect the northern portion of the Biscayne aquifer were recently developed (SFWMD, 2000e). These minimum levels correlate to operation levels for eleven coastal canals as indicated in **Tables 8** and **12**. These levels vary slightly from what was assumed during the Restudy.

Lake Istopokga Demands

Additional pasture land in the lower Lake Istopokga Basin is expected to be converted to sugarcane in the near future, resulting in new demands and runoff. Seasonally and annually varied demands and runoff from the lower Lake Istopokga Basin were used with an average annual demand of 12,000 ac-ft and an average annual runoff of 6,000 ac-ft. Modeling for the LEC Plan assumed Lake Okeechobee would supply the supplemental irrigation water in the incremental simulations.

Seepage from the North of Lake Okeechobee Storage Reservoir

The design of the North of Lake Okeechobee Storage Reservoir in the Restudy did not include seepage from the reservoir back to Lake Okeechobee. The LEC Plan assumed a 50 percent seepage return to the lake. This assumption will need to be reevaluated as more information about the geology of the area and design of the reservoir becomes available.

C-44 Reservoir Modifications

The Indian River Lagoon Feasibility Study (USACE, 1996) recently completed an investigation to optimize the C-44 Reservoir. St. Lucie Estuary targets (**Table 13**), local basin runoff, reservoir size, and operations were also modified. The C-44 reservoir size was reduced to 30,000 acres while the depth has increased to 10 feet. When appropriate, the revised design and operation were incorporated into all simulations performed for the LEC Plan.

Table 13. Revised Performance Targets for the St Lucie Estuary.

Flow Range	Desired Maximum Number of Months in Range
< 350 cfs - monthly	178
> 2,000 cfs - monthly	23
> 3,000 cfs - monthly	5
> 2,000 cfs – 14 -day average	23

ANALYSIS OVERVIEW

In order to determine the effects of existing and proposed water management facilities on water resources and the environment and the ability to meet projected water demands, base case simulations were performed with both the SFWMM and the subregional ground water models.

The first set of simulations represented current (1995) conditions under historic 1995 demands. The second set represented future (2020) demands under identical rainfall conditions with projects expected to be completed by 2020 in place. This includes the Everglades Construction Project, the Lake Okeechobee WSE Schedule, Modified Water Deliveries for Everglades National Park, the C-111 Basin Project, and portions of the *Interim Plan for Lower East Coast Regional Water Supply* (LEC Interim Plan) (SFWMD, 1998b). The third set of simulations, 2020 with Restudy, included the construction projects and operational features of the Restudy that are expected to be in place by 2020. The fourth set, LEC-1, includes all features of the previous simulation plus additional features and operational changes that are specific to this plan, such as redistribution of wellfields, implementation of selected water supply development options, and refinements concerning implementation of the water resource development projects which are being made in the CERP. Areas that performed well were identified by applying the planning criteria and performance measure targets such as MFLs, 1-in-10 year level of certainty, and resource protection criteria.

Given the large number of criteria applied and the large number of areas evaluated in the LEC Planning Area, a simplified approach was used to display evaluations. The performance of a model simulation is summarized as green, yellow, or red for each evaluation criterion, based on the ability to meet an environmental criterion/target. The color provides an assessment of the ability of the plan to achieve the resource protection, recovery, and/or long-term sustainability objectives defined by the performance measure(s) and best professional judgement. Green means that the combination of features in the model simulation is likely to meet the management objective described by the performance measure. Yellow means that achievement of the objective is marginal or uncertain and that improvement is needed or that the hydrologic target is not defined. Red means that the objective may not be met. The color coding scheme is similar to that used in the Restudy to assess the overall performance of the recommended components when compared to the no action alternative.

The Caloosahatchee Basin performance was analyzed in the CWMP. The recommendations made in the CWMP that are pertinent to the LEC planning process can be found in **Chapter 6** of this plan (**Recommendations 28**, **29**, **30**, and **35**).

URBAN AND AGRICULTURAL WATER SUPPLY RESULTS

This section presents and discusses the results of LEC Plan base cases, alternatives, and incremental evaluations with regard to urban and agricultural water supply. Results are first presented for the Lake Okeechobee Service Area (LOSA) and then for the LEC Service Areas (LECSAs): North Palm Beach Service Area, Lower East Coast Service Area 1 (LECSA 1), Lower East Coast Service Area 2 (LECSA 2), and Lower East Coast Service Area (LECSA 3). For each service area, discussion of the results is followed by a summary. The service areas themselves are delineated and described in **Chapter 3**. The results are evaluated in terms of water supply performance goals, which have been described in **Chapter 2** and previously in this chapter. Descriptions of the key assumptions of the base cases, alternatives, and incremental simulations have been presented in the water and land use assumptions section of this chapter.

Lake Okeechobee Service Area

The Lake Okeechobee Service Area (LOSA) includes those areas for which Lake Okeechobee is the primary direct storage source. The major subbasins within the LOSA include the EAA, the Caloosahatchee Basin (C-43 Basin), the St. Lucie Canal Basin (C-44 Basin), the Brighton Seminole Indian Reservation, the Lower Lake Istokpoga Basin, and the Big Cypress Seminole Reservation (see **Figure 17** in **Chapter 3**).

In the LOSA, water supply evaluations were made using the SFWMM which performs simulations for the 31-year period from 1965 through 1995. For the purpose of water supply evaluations in this largely agricultural area, a water year (from October to September), rather than a calendar year, has been used. Thirty complete water years are covered by the simulation period.

Performance Measures Applied

The key water supply performance goal for the LOSA is that no more than three water years with significant water shortages occur during the simulation period. A water shortage is generally considered significant when greater than 100,000 ac-ft of demands are not met. This performance measure is obtained from a frequency of water restrictions performance graphic (see **Figure D-1** in **Appendix D** for an example and **Appendix H** for actual model results), combined with analysis of the total volume of water restricted from a supply-side management report (see **Appendix H**). During the simulations, a water shortage is recorded when the SFWMM recognizes that regional water storage conditions occur which meet the conditions under which the District will impose supply-side management restrictions on the LOSA. Supply-side management procedures and their application within the LEC Plan evaluations are more completely explained in **Chapter 3**.

If there are significant supply-side management cutbacks during more than three of the water years in the simulation period, the goal of providing a 1-in-10 year level of certainty is not met. One way to look at the significance of these events is to consider the supply-side management cutback volumes for the fourth and fifth worst drought years in a simulation. This information is provided in the last row of the information tables in the results sections below. In considering the supply-side management volumes, it is important to remember that the LOSA contains 600,000 to 700,000 acres of irrigated lands, so that 100,000 ac-ft of supply-side cutbacks implies a delivery deficit of about two inches spread over the irrigated lands in the service area during a 12-month crop year.

Base Cases and Alternatives Results

Information regarding the water supply performance under the base cases and alternatives is presented in **Table 14**. The first row in **Table 14** provides the number of water years with significant water shortage events while the second row provides the total number of water years in which any water shortage event occurs. The remaining information in **Table 14** further clarifies the significance of the water restrictions and the performance pattern that may be achieved through 2020.

1995 Base Case. Water restrictions occur for eight of the 30 water years simulated in the 1995 Base Case and the total number of months of water shortages are 32. The supply-side management cutback volumes were high (over 300,000 ac-ft) for all of the three worst drought years. The supply-side management volumes in the fourth and fifth worst cutback years were 125,000 and 64,000 ac-ft, respectively. The 125,000 ac-ft of restrictions in 1990 indicated an inability to meet the 1-in-10 year level of certainty goal.

Table 14. Information on All Water Restrictions in the SFWMM Simulations for the Base Cases and Alternatives for the Lake Okeechobee Service Area.

	1995 Base Case	2020 Base Case	2020 with Restudy	LEC-1
Number of water years with significant shortages	4	9	3	2
Number of water years with shortages in one or more months	8	16	5	5
Total months of water shortages	32	79	23	18
Total supply-side management cutback volume (ac-ft) for 31-year period	1,419,000	3,894,000	859,000	709,000
Supply-side management cutback volumes for the three worst drought years	1981 - 509,000 1974 - 355,000 1982 - 318,000	1974 - 491,000 1990 - 490,000 1981 - 435,000	1981 - 464,000 1982 - 212,000 1990 - 135,000	1981 - 381,000 1982 - 182,000 1990 - 81,000
Supply-side management cutback volumes for the fourth and fifth worst drought years	1990 - 125,000 1973 - 64,000	1982 - 396,000 1989 - 388,000	1974 - 20,000 1991 - 16,000	1976 - 30,000 1978 - 18,000

2020 Base Case. Water restrictions occurred for 16 of the 30 water years simulated in the 2020 Base Case and the total number of months of water shortages were 79. As with the 1995 Base Case, the supply-side management cutback volumes were high (over 300,000 ac-ft) for all of the three worst drought years. The supply-side management cutback volumes for the fourth and fifth worst years were close to 400,000 acre feet, which could easily lead to significant crop losses. In fact, cutbacks over 100,000 ac-ft occurred in nine of the years.

2020 with Restudy. The 2020 with Restudy simulation had five years with water restrictions and the total number of months of water shortages for the 2020 with Restudy were 23. The second and third worst years were significantly lower (212,000 and 135,000 ac-ft, respectively) for the 2020 with Restudy than for the base cases. The fourth and fifth worst years had restrictions of 20,000 and 16,000 ac-ft, respectively. The volumes of these cutbacks would not lead to significant crop losses. Based on the supply-side management cutbacks, the 2020 with Restudy alternative met the 1-in-10 year level of certainty goal for the LOSA.

LEC-1. The LEC-1 simulation also had five years with water restrictions. The total months of water shortages for this simulation were 18. The supply-side management cutback volumes were lower than those for the 2020 with Restudy and would not lead to significant crop losses. Based on the supply-side management cutbacks, the LEC-1 met the 1-in-10 year level of certainty goal for the LOSA. Supply-side management cutbacks were greater than 100,000 ac-ft and would be considered significant in only two of the years simulated.

Incremental Results

Information regarding the water supply performance in the incremental simulations is presented in **Table 15.** The first row in **Table 15** shows the number of water years with significant water shortage events while the second row provides the number of water years in which any water shortage event occurs. The remaining information in **Table 15** further clarifies the significance of the water restrictions and the performance pattern that may be achieved through 2020.

Table 15. Information on Water Restrictions in the SFWMM Incremental Simulations for the LOSA.

	1995 Revised Base Case	2005	2005 SSM Scenario	2010	2015	LEC-1 Revised
Number of water years with significant shortages	5	7	5	6[a]	3	1
Number of water years with shortages in one or more months	9	11	7	9	6	4
Total months of shortages	37	47	35	36	21	12
Total supply-side management cutback volume (ac-ft) for 31-year period	1,878,000	2,571,000	1,693,000	1,496,000	860,000	432,000
Supply-side management cutback volumes for three worst drought years	1982 - 461,000 1974 - 417,000 1981 - 339,000	1981 - 472,000 1974 - 463,000 1982 - 462,000	1982 - 445,000 1974 - 403,000 1981 - 312,000	1974 - 390,000 1981 - 379,000 1982 - 201,000	1981 - 305,000 1974 - 233,000 1976 - 145,000	1981 - 294,000 1982 - 95,000 1990 - 31,000
Supply-side management cutback volumes for fourth and fifth worst drought years	1973 - 228,000 1990 - 197,000	1973 - 351,000 1990 - 320,000	1973 - 213,000 1990 - 171,000	1976 - 148,000 1973 - 129,000	1982 - 102,000 1990 - 56,000	1978 - 5,000

a. Performance could be improved by continuing supply-side flexibility or other option applied to 2005 SSM Scenario through 2010.

1995 Revised Base Case. The number of water years with water restrictions for the 1995 Revised Base Case simulations were nine and the total number of months of water shortages were 37. These were worse than the original 1995 Base Case due primarily to the inclusion of revised Caloosahatchee hydrology and agricultural demands and the inclusion of the Seminole Big Cypress Reservation demands in the revised simulation. The supply-side cutback volumes were high (over 300,000 ac-ft) for the three worst drought years in the 1995 Revised Base Case simulation. The supply-side management cutback volumes for the fourth and fifth worst years were 228,000 and 197,000 ac-ft, respectively, which represented significant delivery deficits.

2005. The total number of years with water shortages (11) and total number of months of water shortages (47) increased during the 2005 incremental simulation. The supply-side cutback volumes were over 400,000 ac-ft for all of the three worst drought years and the fourth and fifth worst drought years still had significant shortages with supply-side management cutback volumes over 300,000 ac-ft. The increase in shortages between the 1995 Base Case and 2005 simulations can be attributed to a number of factors: 1) the implementation of the Everglades Construction Project in combination with the Lake Okeechobee WSE regulation schedule allowed more lake water to be transferred to the WCAs, which resulted in a lower lake level going into some drought years; 2) the incorporation of rain-driven schedules for the WCAs and Everglades National Park resulted in more urban area demand being satisfied by Lake Okeechobee and less reliance on the WCAs for urban water supply; 3) an increase in agricultural demand in the Lake Istokpoga Service Area was satisfied by Lake Okeechobee in order to achieve environmental objectives in Lake Istokpoga; and 4) land taken out of production for the Everglades Construction Project resulted in an increase in agricultural demand in the Caloosahatchee Basin. These additional demands were expected to occur prior to completion of any significant storage features recommended by the Restudy.

2005 SSM Scenario. With the operational flexibility of the supply-side management criteria, the total number of years with shortages was reduced to seven in the 2005 SSM Scenario. The total number of months of water shortages (35) was also reduced in this simulation. Two of the worst shortages in the 2005 SSM Scenario were over 400,000 ac-ft and the third was just over 300,000 ac-ft. This performance was better than both the original 2005 incremental simulation and the 1995 Revised Base Case. The volumes of cutbacks were 213,000 and 171,000 ac-ft for the fourth and fifth worst droughts, respectively, which represent improvements over the volumes of cutbacks in the 1995 Revised Base Case. Modification of the supply-side management criteria, or an equivalent operational schedule change, would improve upon the ability to achieve a 1-in-10 year level of certainty in the LOSA.

2010. The total number of years with shortages in the 2010 incremental simulation was nine and the total number of months of water shortages was 36. In this simulation, the volume of cutbacks was significantly less than that of the 1995 Revised Base Case, even though the years and months of shortages were about the same. For the 2010 incremental simulation, the worst two years had close to 400,000 ac-ft of supply-side shortages while the third worst year had significantly less cutbacks at 201,000 ac-ft. The cutbacks for the fourth and fifth worst drought years were 148,000 and 129,000 ac-ft, respectively, which were substantially less than previous simulations. This was the first sign that Restudy infrastructure is making water supply conditions better than the 1995 Revised Base Case. The 2010 performance could be improved further by implementing an interim operational change such as modification of the supply-side management criteria.

2015. The total number of years with shortages (six) and the total number of months of water shortages (21) for the 2015 incremental simulation were reduced when compared to previous simulations. The improvement in supply-side cutback volumes which began in the 2010 simulation continued in the 2015 simulation. The third worst supply-side management event shows only 145,000 ac-ft of supply-side management cutbacks. The fourth and fifth worst years had supply-side management cutbacks of 102,000 and 56,000 ac-ft, respectively, and it is unlikely that they would cause significant reductions in crop yields. The 1-in-10 year level of certainty was met during the 2015 simulation.

LEC-1 Revised. The LEC-1 Revised simulation's performance improved when compared to the original LEC-1 simulation. The chief reasons for this appear to be the changed configuration and operations of the EAA Storage Reservoirs, capture and storage of runoff from the Hillsboro Basin, and use of water from the C-51 and West Palm Beach ASR systems to meet demands in the EAA. The total number of months of water shortages and the volumes of cutbacks were reduced when compared to previous incremental simulations. The third worst supply-side management event had only 31,000 ac-ft of cutbacks and the fourth worst year of cutbacks was only 5,000 ac-ft, which is clearly insignificant. The results indicate that the LEC-1 Revised alternative met the 1-in-10 year level of certainty.

Summary of Results for the Lake Okeechobee Service Area

- The poor water supply performance of the 1995 and 2020 base cases indicated that significant water resource development efforts will be needed to achieve a 1-in-10 year level of certainty for water users in the LOSA.
- The 2020 with Restudy, LEC-1, and LEC-1 Revised model simulations, which contain the projects recommended in the Restudy as their primary water resource development components, were capable of meeting 1-in-10 year level of certainty performance within the LOSA.
- The incremental simulations indicate improvements to the ability to meet the LOSA's demands will occur as Restudy projects are implemented and performance improves between 1995 and 2020.
- The incremental simulations indicate that the 1-in-10 year level of certainty water supply performance can be met by 2015 in the LOSA.
- The incremental simulations indicate that optimization in the design and operation of the Restudy projects can significantly improve the performance that was originally estimated in the Restudy. These refinements to the Restudy projects will be included in the recommendations to the CERP.
- Actions such as CERP acceleration, changes to supply-side management criteria, or other operational improvements are

needed to reduce the risk of water shortage losses in the interim period. The 2005 SSM Scenario demonstrated that flexibility in the application of supply-side management is one tool that could be used to meet water demands during droughts in the interim period until water resource development projects were completed. Other operational options should also be investigated.

Specific Analyses Related to the Seminole Tribe of Florida

In 1996, the *Agreement Between the South Florida Water Management District and the Seminole Tribe of Florida Providing for Water Quality, Water Supply, and Flood Control Plans for the Big Cypress Seminole Indian Reservation and the Brighton Seminole Indian Reservation, Implementing Section V.C. and VI.D. of the Water Rights Compact* (Seminole Agreement) was executed. The Seminole Agreement obligated the District to conduct several studies related to the quantity of surface water supply for the Big Cypress Seminole Indian Reservation. Additional studies related to water supply for the Brighton Seminole Indian Reservation were also agreed upon. As required, the studies are included as integral parts of the District's LEC regional water supply planning effort. While analyses of these issues are included in this plan, the Seminole Agreement obligates the District to give ongoing consideration of impacts to the Seminole Tribe's rights as plans and/or changes are reviewed in the future. The Seminole Agreement states the Big Cypress Seminole Indian Reservation studies will determine the following:

- The amount and timing of deliveries needed for hydroperiod restoration in the northwest corner of WCA-3A, as a part of Everglades Forever Act implementation
- The potential effect of the Everglades Program on the tribe's ability to use the alternative water supply delivery system (contemplated in Subsection 6) on the Big Cypress Seminole Indian Reservation resulting from diversion of the C-139 Basin and, if diverted, the C-139 Annex
- The potential effect of revising Lake Okeechobee's regulation schedule on available water supply for the Big Cypress Seminole Indian Reservation, if water from Lake Okeechobee is part of the water supply for the reservation
- The potential effect of District water supply plans and Everglades hydropattern changes, which may be developed and adopted in the future, on available surface water supplies from Lake Okeechobee for the Brighton Seminole Indian Reservation
- The potential effect of changes to Lake Okeechobee's regulation schedule, which may be developed and adopted in the future, on available surface water supplies from Lake Okeechobee for the Brighton Seminole Indian Reservation

- The potential effect, if any, of implementation of the Everglades Program on the available surface water supplies from Lake Okeechobee for the Brighton Seminole Indian Reservation

A summary of the District’s efforts in regard to these studies is summarized below.

Northwestern Corner of WCA-3A Hydroperiod Restoration. As part of the LEC regional water supply planning process, District staff utilized measures of hydroperiod (inundation duration), and the number of times high water criteria were exceeded, and the number of times water fell below the low water criteria to evaluate simulated performance in northwestern corner of WCA-3A under various modeled alternatives. These performance measures and the results of the evaluations are described in detail in the **Environmental Resources Results** section of this chapter. In summary, under current conditions (simulated by the 1995 Base Case) hydroperiod performance in the northwestern corner of WCA-3A failed to achieve desired targets, while in the 2020 with Restudy simulation, hydroperiods in the same area either met or exceeded the performance targets established in the planning process for hydroperiod restoration.

Effect of the Everglades Program. The Everglades Program's projects are included in the assumptions for alternatives modeled for the LEC Plan. The effect on the Seminole Tribe of Florida of these assumptions is evident by comparison of the 1995 Base Case (without Everglades Program projects) with results of alternative model simulations, that include the Everglades Program projects. Historically, the Big Cypress Seminole Indian Reservation did not rely upon surface water deliveries from the L-4 Canal. Because the Everglades Program and the Seminole Agreement contemplate surface water deliveries to Big Cypress Seminole Indian Reservation via pump station G-409, the Seminole Tribe's water demands are included as input files in the model simulations performed for the LEC water supply planning process. The amount and timing of these water deliveries were determined using demand estimates based on land use projections in the 2010 incremental simulation and calculated over the 31-year simulation period using the Blaney-Criddle method. These deliveries exceed the Seminole Tribe's surface water entitlement as established in the Final Order 98-115 DAO, except in wet months when demands were less than the entitlement (**Figure 25**). In summary, the Seminole Tribe's surface water demands are satisfied most of the time from a variety of sources. As projects associated with the CERP and the LEC regional water supply planning effort become operational, modeling indicates the Seminole Tribe's unmet demands decrease from 15 percent in the 1995 Base Case to less than two percent of the time by 2020. Due to Big Cypress Seminole Indian Reservation reliance on Lake Okeechobee supplies, the effects of regulation schedule changes on the Big Cypress Seminole Indian Reservation are integrated in these results, as described below.

Effects of Lake Okeechobee Regulation Schedule Changes. Lake Okeechobee's regulation schedule is an integral component of each alternative model simulation. Since various Lake Okeechobee regulation schedules were considered, several model simulations were completed to assess the effects of Lake Okeechobee's regulation schedule, as well as other C&SF Project modifications. As noted above, the Seminole Tribe's surface water demands for both the Big Cypress Seminole Indian Reservation and the Brighton Seminole Indian Reservation were included in input files, where applicable, for these model simulations. **Tables 16** and **17** specify the Lake Okeechobee regulation schedule used for each simulation.

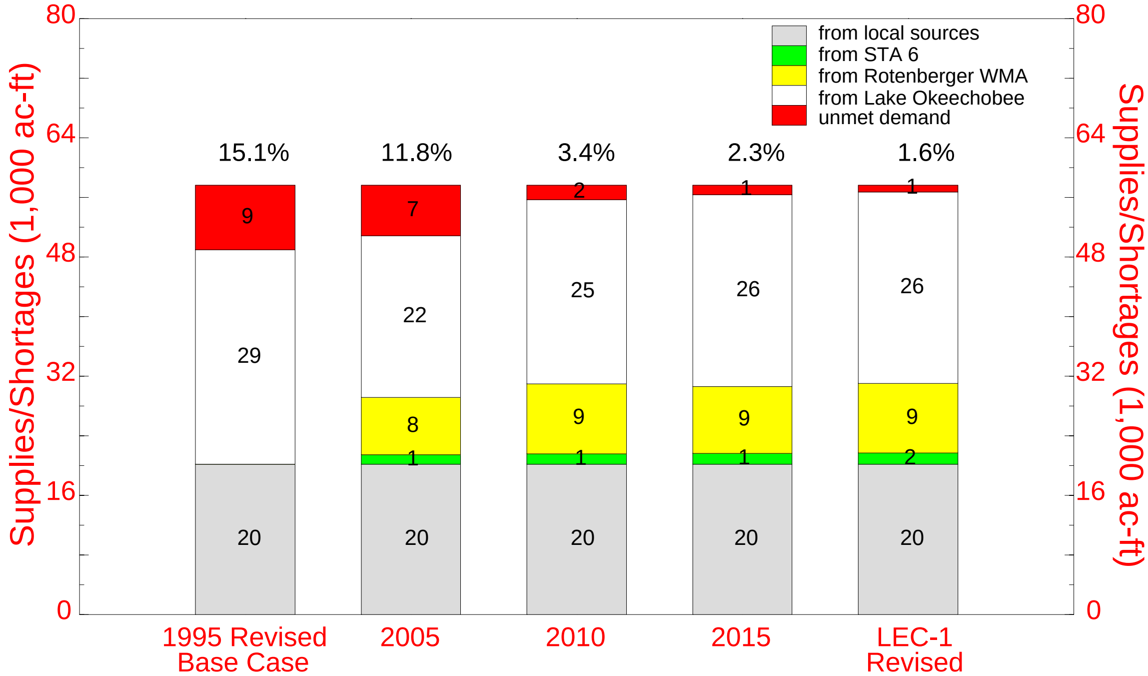

Figure 26. Average Annual (1965-1995) Irrigation Supplies and Shortages for the Seminole Tribe Big Cypress Reservation. The data on top of each bar represents the percentage of unmet demands.

Table 16. Comparison of Assumptions for the Base Case and Alternative Simulations.

Simulation	Lake Okeechobee Schedule
1995 Base Case	Run 25
2020 Base Case	WSE
2020 with Restudy	Run 25 modified for Restudy components
LEC-1	WSE modified for Restudy components

Table 17. Assumptions for the Incremental Model Simulations by SFWMM.

Simulation	Lake Okeechobee Schedule
1995 Revised Base Case	Run 25
2005	WSE
2005 SSM Scenario	WSE modified for supply-side management
2010	WSE modified for Restudy components
2015	WSE modified for Restudy components
LEC-1 Revised	WSE modified for Restudy components

Given the operational components and agreements between the District and the Seminole Tribe, additional matters related to the Brighton Seminole Indian Reservation must be considered. The Seminole Agreement reserves a volume of water from Lake Okeechobee for the Seminole Tribe, integrates supply from Lake Okeechobee to meet the Seminole Tribe's entitlement, and establishes operational criteria for water shortages. Generally, the operational criteria are based upon canal water elevations. Pump stations G-207 and G-208 have intake elevations at 10 feet, which are also integral to the ability of the pumps to provide Lake Okeechobee water to the Brighton Seminole Indian Reservation. Analysis of Lake Okeechobee stage duration curves indicates that Lake Okeechobee levels drop below 11 feet (where pump efficiency is reduced) four to five percent of the time in the LEC-1 simulation compared to three percent of the time that observed lake stages dropped below 11 feet during the 1952 to 1977 period (Marban and Trimble, 1988).

Lower East Coast Service Areas

For planning purposes, the coastal areas east of the Everglades has been divided into four service areas: North Palm Beach Service Area, LEC Service Area 1 (LECSA 1), LEC Service Area 2 (LECSA 2), and LEC Service Area 3 (LECSA 3). The service areas generally reflect the historical sources of water delivered from the regional system. LECSA 1 includes coastal basins, which receive water from WCA-1. Likewise LECSA 2 and LECSA 3 include coastal basins which receive water from WCA-2 and WCA-3, respectively. The North Palm Beach Service Area has historically received water from Lake Okeechobee via the L-8 and the M canals. More complete descriptions of these areas and figures showing their extent (**Figures 19**, **20**, **21**, and **22**) are provided in **Chapter 3**.

Two situations will cause declarations of water shortages to be simulated in the these service areas. The first situation occurs when supply-side management is imposed in the LOSA for longer than seven days. This indicates that water from regional storage might not be available and cutbacks in usage and deliveries at this time may be needed to save water for more crucial times later in the dry season. The other situation occurs when ground water levels at coastal saltwater intrusion monitoring locations indicate that water restrictions are necessary to minimize saltwater intrusion. Note that the SFWMM can only provide generalized indications regarding water levels at coastal saltwater intrusion monitoring locations because of the large (two-mile by two-mile) grid cell size used in this model. Because of this limitation, performance at the coastal ground water monitoring locations is also analyzed in the subregional ground water models. The incremental simulations do not include results from the subregional ground water models for the LEC service areas and, therefore, the incremental analyses should be considered preliminary and are not indicative of future performance.

SFWMM Base Cases and Alternatives Results

During the 30 water years simulated, the numbers of years water restrictions occurred within the LEC service areas due to Lake Okeechobee supply-side management were five for the 1995 Base Case, 11 for the 2020 Base Case, three for the 2020 with

Restudy, and two for the LEC-1. These data are presented together for the entire service area, since any shortage declarations apply equally to all of the coastal basins. The number of such shortages for both the 1995 and 2020 base cases were excessive and indicate the inadequacy of regional storage in the absence of major water resource development projects. The number of years of water shortages for the 2020 with Restudy and LEC-1 simulations indicated that the components recommended by the Restudy can provide a 1-in-10 year level of certainty for the LEC service areas. It should be noted, that in all cases, these declarations were for Phase I and Phase II shortages and restrictions that pose an inconvenience to users, but were not likely to result in economic losses. A more detailed discussion of water shortage phases is provided on **pages 25** through **28** in **Chapter 2**.)

The information in **Table 18** summarizes the modeled frequency of water shortage declarations that occurred due to coastal saltwater intrusion water level criteria. These data are presented for each service area since water shortages are usually declared based on local resource conditions.

Table 19 presents tabulations of the number of times water shortages were triggered by local ground water conditions based on trigger well locations. Amounts and locations of withdrawals significantly affected coastal saltwater intrusion problems. Both SFWMM and subregional ground water model results were analyzed to determine if a 1-in-10 year level of certainty was met. The subregional ground water results are discussed later in this section, following the SFWMM discussion.

Table 18. Number of Years with Water Restrictions Caused by Local Triggers in the Base Case and Alternative SFWMM Simulations for the Lower East Coast Service Areas During the 30 Water Years Simulated.

Service Area	1995 Base Case	2020 Base Case	2020 with Restudy	LEC-1
North Palm Beach Service Area	5	0	0	0
LECSA 1	7	8	0	0
LECSA 2	21	23	2	12
LECSA 3	3	3	2	2

1995 Base Case. Water shortages occurred in significant numbers in the 1995 Base Case in all service areas except LECSA 3, where regional wellfields have been established inland from areas subject to saltwater intrusion. Ground water level monitoring locations in the Tequesta, Jupiter, Lake Worth, Fort Lauderdale Airport, Hollywood, and Homestead areas accounted for most of the shortages. A 1-in-10 year level of certainty performance was not met in this simulation.

2020 Base Case. In the 2020 Base Case, which uses the utility preferred locations for future withdrawals, significant numbers of water shortages caused by local triggers occurred only in LECSA 1 and LECSA 2. Ground water level monitoring trigger events in the North Palm Beach Service Area had been eliminated, most likely due to

Table 19. Number of Times Water Restriction Triggers in the SFWMM Base Case and Alternatives for the Lower East Coast Service Area Were Triggered.[a]

Trigger Well	1995 Base Case	2020 Base Case	2020 with Restudy	LEC-1	LEC-1A
Tequesta	5				
Jupiter	4				
Gardens					
Lake Worth	11	13			
Pompano	1				
North Lauderdale	3	3	3	3	
Lauderdale	4	19 + (4)			
Fort Lauderdale Airport	27 + (1)	31 + (2)	1	2	
Hollywood	54 + (2)	61 + (6)	4	17	
North Miami Beach	1	1			
Miami		1			
Cutler Ridge	1	6			
Homestead	5	5			
Florida City	2	3			
Taylor	3	4	5	5	5

a. Phase 2 in parentheses, all others are Phase 1

assuming that a recharge canal exists and the use of Floridan aquifer water was increased. Lake Worth, Fort Lauderdale Airport, and Hollywood areas continued to indicate low ground water levels. Trigger events increased in Lauderdale and Cutler Ridge compared to the 1995 Base Case. A 1-in-10 year level of certainty performance was not met in this simulation.

2020 with Restudy. In the 2020 with Restudy model simulation, not only was the Restudy infrastructure through 2020 modeled as having been completed, but significant public water supply demands were redistributed within the service area as well. Eastern wellfields at Miramar, Hollywood, Broward County 3A/3B/3C, Dania, and Hallandale were assumed to be placed on standby, with their entire demands met from western facilities. The following utilities had a portion of their demands shifted inland: Riviera, Lake Worth, Manalapan, Lantana, Boca Raton, and Florida City. These assumptions were consistent with the Restudy's recommendations. Based on coastal ground water levels, all four service areas met the 1-in-10 year level of certainty. No ground water level triggering occurred in the North Palm Beach Service Area or LECSA 1 during the 2020 with Restudy simulation (**Table 18**). In LECSA 3, the two years of locally triggered water shortages can be discounted because they were caused exclusively by the Taylor monitoring location, which triggered even when public water supply withdrawals were eliminated (see results for the LEC-1A simulation). The two cutback events that occurred in LECSA 2 were caused by coastal ground water level monitoring locations in the Hollywood, North Lauderdale, and Fort Lauderdale Airport areas. These events occurred during 1971 and 1975 and not during the 1-in-10 drought year identified and used for the ground water model simulations discussed below. The 2020 with Restudy simulation solved the low ground water level in this area, as seen in the 2020 Base Case, by placing the coastal wellfields in southeast Broward County on standby.

LEC-1. In the LEC-1 model simulation, not only was the Restudy infrastructure through 2020 modeled as complete, but different wellfield withdrawals and distributions were modeled compared to the 2020 with Restudy. In the LEC-1 model simulation, North Palm Beach Service Area, LECSA 1, and LECSA 3 met the 1-in-10 year level of certainty based on coastal ground water conditions. No ground water level triggering occurred in the North Palm Beach Service Area or LECSA 1 during the LEC-1 simulation. In LECSA 3, only the same nonwithdrawal related triggers occurred at Taylor. However, twelve years of coastal saltwater intrusion triggers occurred in LECSA 2 (**Table 18**). They primarily occurred at the coastal ground water level monitoring location in the Hollywood area. A few triggers also occurred in the North Lauderdale and Fort Lauderdale Airport areas (**Table 19**). In this case, restrictions did occur during the 1-in-10 drought year that was identified and used for the subregional ground water model simulations discussed below. Because the utility preferred locations for withdrawals were the basis for the LEC-1 simulations, a greater volume of public water supply withdrawals remained at the current locations along the coast near the saline interface than in the 2020 with Restudy simulation, especially in southeast Broward County. The potential for saltwater intrusion due to public water supply withdrawals was high and this area was very sensitive to public water supply withdrawal amounts and locations simulated in LEC-1. The utility preferred locations as modified in LEC-1 indicated that a smaller volume of withdrawals may need to be moved away from the coast than was moved during the 2020 with Restudy simulation. The higher number of water restrictions in LEC-1 in the Hollywood area could be reduced to meet a 1-in-10 year level of certainty as seen in the 2020 with Restudy simulation. Model iterations with different wellfield distributions would demonstrate this.

The SFWMM simulations indicated that with the planned water resource development projects and appropriate water supply development (in the form of locations of demands that meet existing permit criteria), water shortages will occur only about one year in ten. It is important, however, to look at the ability to meet demands during a 1-in-10 year drought event with the high resolution ground water models. This is the focus of evaluation of subregional ground water model results.

Subregional Ground Water Models Base Case and Alternatives

The numbers of years when water restrictions within the LEC service areas were caused by Lake Okeechobee supply-side management during the 30 water years simulated were five for the 1995 Base Case, 11 for the 2020 Base Case, three for the 2020 with Restudy, and two for the LEC-1. These data are presented together for all of the service areas since any shortage declarations apply equally to all of the coastal basins. The number of such shortages for the 1995 and 2020 base cases were excessive and indicated the inadequacy of regional storage in the absence of major water resource development projects. The number of years of water shortages for the 2020 with Restudy and LEC-1 simulations indicated that the components recommended by the Restudy can provide a 1-in-10 year level of certainty for the LEC service areas.

Five subregional ground water models were used to evaluate the ability to meet a 1-in-10 year level of certainty in the LEC service areas. They provided a more detailed look at water conditions compared to the SFWMM, because of their fine grid cell size, generally 500-feet by 500-feet, compared to the two-mile by two-mile cell for the SFWMM. Because of the detail involved in simulations of these models, they were the primary tool used to evaluate performance during a historic period that closely matches a 1-in-10 year drought event. This detail allowed performance to be evaluated in terms of three water resource conditions during that 1-in-10 year drought event:

- The triggering of water shortages was evaluated based on water levels at selected monitoring locations. This measure paralleled the water shortage triggering evaluated in the SFWMM, but provided much more location specificity, because of the fine grid cell size.

- Potential movement of the saltwater interface was evaluated by considering the net westward flow across the present location of the saltwater interface for the year that represented the 1-in-10 year drought condition.

- Potential impacts on wetlands were evaluated by considering ground water level drawdown events of one foot or more under identified wetland areas. An event occurred when the 30-day average head differed, between the simulation and the no consumptive use withdrawals simulation, by one foot or more.

Despite the detail of the ground water models, the model results are not predictive. They are not necessarily representative of actual local conditions, either now or in the future. Thus, failure to identify problems in the model simulations in this plan does not ensure issuance, reissuance, or modification of water use permits, nor does it ensure that a problem does not exist.

Results of the evaluations of the ground water model results for the 2020 with Restudy and LEC-1 alternatives, with respect to the three performance areas, are presented in **Table 20.**

Table 20. Water Supply Results for Ground Water Model Simulations of the 2020 with Restudy and the LEC-1 Alternatives.[a]

Water Restriction Area	Coastal Water Shortage Triggers During LEC 1-in-10 Year Drought Conditions	Net Westward Ground Water Flow at the Saltwater Interface During LEC 1-in-10 Year Drought Conditions	Impacts on Isolated Wetlands During LEC 1-in-10 Year Drought Conditions
North Palm Beach			
Jupiter	No indicated problems	Tequesta: Locally, west flows intersected the interface. Probably related in part to individual well withdrawal distribution and model cell size.	Seacoast, Jupiter, and Riviera Beach: Numerous wetlands affected by drawdown events. Need to verify location and condition of wetlands inside one-foot drawdown.
Clear Lake	Riviera Beach: Results for PB-632 trigger well appeared to be very sensitive to how much pumpage was east of C-17. LEC-1 has limited pumpage to the east and shows no triggering. 2020 with Restudy has all withdrawals east of C-17 and triggers Phase 2 shortages. Results for PB-809 show some triggering in LEC-1 associated with operations of ASR wells during dry periods. This problem does not appear in the 2020 with Restudy simulation.	Riviera Beach: Westward ground water flows intersected the interface in both LEC-1 and 2020 with Restudy.	No indicated problems
Palm Beach Gardens	No indicated problems	No indicated problems	No indicated problems
LEC Service Area 1			
Lake Worth	No indicated problems	No indicated problems	Lake Osborne ASR wells showed wetlands affected by drawdown events. Some wetlands are connected to and controlled by the lake, others are not.
Royal Palm Beach/ Wellington	No indicated problems	No indicated problems	No indicated problems
Delray Beach	No indicated problems	No indicated problems	Palm Beach County Utilities and Delray Beach: Few scattered wetlands affected by drawdown events from wellfields along and east of the Turnpike. The location and condition of wetlands need to be verified.
Boca Raton	No indicated problems	Boca East Wellfield: Westward flow at the interface	No indicated problems
Boca Raton West	No indicated problems	No indicated problems	Boca's west wellfield: Wetland to the east affected by drawdown events. Configuration suggests this may be excavated and not natural wetland.
LEC Service Area 2			
Pompano Beach	No indicated problems	Pompano: Westward flow across the interface in LEC-1 and 2020 with Restudy.	Pompano's east wellfield: A wetland east of the wellfield was affected by drawdown events. Need to verify location and condition of wetland.

Table 20. Water Supply Results for Ground Water Model Simulations of the 2020 with Restudy and the LEC-1 Alternatives.[a] (Continued)

Water Restriction Area	Coastal Water Shortage Triggers During LEC 1-in-10 Year Drought Conditions	Net Westward Ground Water Flow at the Saltwater Interface During LEC 1-in-10 Year Drought Conditions	Impacts on Isolated Wetlands During LEC 1-in-10 Year Drought Conditions
Fort Lauderdale Airport	Potential saltwater intrusion problems triggers were sensitive to location of withdrawals. Geographic distribution of wellfield withdrawals in 2020 with Restudy did not trigger shortages, while the distribution in LEC-1 did.	Dixie: Slight west flow across the interface in LEC-1.	Fort Lauderdale Airport: A wetland southeast of wellfield was affected by drawdown events and should be verified.
Hollywood	No indicated problem, but the trigger well is east of C-10 and may not reflect problems caused by withdrawals at Hollywood's wellfields in LEC-1.	Hollywood: Westward flow across the interface in LEC-1	No indicated problems
Western Broward County	No indicated problems	No indicated problems	Sunrise: Wetlands near Broward County South Regional Wellfield and Miramar were affected by drawdown events. Size and shape of wetlands suggest excavations, not natural. City of Coral Springs and North Springs Improvement District: Scattered wetland was affected by drawdown events. Coral Springs Improvement District: Wetlands at the edge of the one-foot contour.
North Miami Beach	No indicated problems	North Miami: Westward flow across interface in LEC-1 and 2020 with Restudy, based on 4.45 MGD with balance of demands from WASD Northwest wellfield in LEC-1. North Miami Beach: OK at 15 MGD with balance of demands from WASD Northwest wellfield in LEC-1.	No indicated problems
LEC Service Area 3			
Miami	No indicated problems	Hialeah-Preston: Westward flow across the interface which may have been due to surface drainage features	Northwest wellfield: Extensive wetlands affected by drawdown events in the area are likely to have been mitigated under existing permit.
Kendall	No indicated problems	No indicated problems	No indicated problems
Kendall Lakes	No indicated problems	No indicated problems	No indicated problems
Homestead	No indicated problems	Rex-Homestead area: Significant westward flow across interface in 2020 with Restudy	West wellfield: Wetlands affected by drawdown events in Bird Drive mitigation areas

a. This table generally summarizes conditions observed in ground water models of the LEC Planning Area. Model results are not predictive, are regional and generalized in nature, and not necessarily representative of actual local conditions, either now or in the future. Please note that a determination of no problems from a model simulation does not ensure issuance, reissuance, or modification of water use permits, nor does determination of a problem preclude it.

The 1-in-10 year level of certainty was met in the 2020 with Restudy and LEC-1 simulations. A summary of water restrictions due to coastal ground water levels in all of the base cases and alternatives from the ground water models is presented in **Table 21**. In most areas, the coastal water shortage triggers did not trigger a water restriction during an 1-in-10 year drought event. In the isolated cases where model results indicated problems, changing withdrawal locations or other operations enabled the water shortage criteria for coastal ground water levels to be met. These isolated events are discussed below:

- Results for the LEC-1 simulation indicated that low ground water levels at PB-632 in the Riviera Beach Area, which were evidenced in the 2020 with Restudy simulation, can be avoided by shifting public water supply withdrawals to Riviera Beach's proposed wellfields located farther west, but within the constraints of the landfill.
- The restrictions associated with the PB-809 trigger in the Clear Lake area in the 2020 with Restudy simulation appeared to result from the assumption that ASR wells in the area would be injecting during dry periods. An appropriate response would be to stop injecting during this period in the model simulation. This assumption was incorporated into LEC-1.
- In the Fort Lauderdale Airport area (LECSA 2), the trigger well is sensitive to wellfield withdrawal distributions. The 2020 with Restudy simulation did not trigger shortages in this area, but the LEC-1 simulation did. A slight change in distribution within the Dixie Wellfield would prevent these low ground water levels and resulting restrictions in LEC-1. It is important to note that, while there were no restrictions in the Hollywood area in LEC-1, the location of the trigger well, east of the C-10 Canal, may have precluded it from accurately assessing saltwater intrusion effects of the Hollywood withdrawal. The aquifer recharge provided by the Broward County Secondary Canal System from the C-9 created a mound that effectively protects the trigger cell (F-219) from effects of withdrawals in the Hollywood's south wellfield. The effectiveness of the recharge facility, timing of construction, and public water supply demands need to be assessed during the CUP process.
- Most wellfields in LECSA 3 avoided water restrictions due to low ground water levels along the coast, because they are centralized inland in Miami-Dade County.

Generally, the distribution of public water supply withdrawals in the 2020 with Restudy simulation did not perform well due to the wellfield distribution assumed. The water supply demands simulated in the LEC-1, which was based primarily on the utility-preferred withdrawal locations and sources, were met.

Indications of net westward ground water flows at the saltwater interface were noted in about half of the water restriction areas under the 1-in-10 year drought conditions. In several cases, the westward ground water flow across the saltwater interface occurred in

Table 21. The Number of Days Each Water Restriction Area Was Cutback in the LEC Service Areas Due to Local Ground Water Conditions.

LEC Service Area	Water Restriction Area	Subregional Ground Water Model Simulation			
		1995 Base Case	2020 Base Case	2020 with Restudy	LEC-1
North Palm Beach Service Area	Jupiter	127	0	112	0
North Palm Beach Service Area	Palm Beach Gardens	0	0	112	0
North Palm Beach Service Area	Clear Lake	0	0	75	19
LECSA 1	Royal Palm Beach	0	0	112	0
LECSA 1	Wellington	0	0	0	0
LECSA 1	Lake Worth	0	114	0	0
LECSA 1	Delray Beach	0	0	0	0
LECSA 1	Boca Raton	0	0	0	0
LECSA 1	Boca West	0	0	14	0
LECSA 2	Western Broward	0	0	0	0
LECSA 2	Pompano	0	0	0	0
LECSA 2	Fort Lauderdale Airport	157	188	0	42
LECSA 2	Hollywood	194	192	0	0
LECSA 2	North Miami Beach	0	0	0	0
LECSA 3	Kendall Lakes	0	0	0	0
LECSA 3	Miami	0	0	0	0
LECSA 3	Kendall	0	0	0	0
LECSA 3	Homestead	0	0	0	0

one alternative and not the other. This is indicative that redistribution of wellfield withdrawals should be avoided (refer to **Appendix H** for the performance measures graphics). Also, indications of drawdowns greater than one foot for more than 30 days beneath wetlands occurred in about half of the water restriction areas under the 1-in-10 year drought conditions. In many instances, the existence and nature of the mapped wetland areas needed to be verified. Also, sometimes the impacts shown were known and had been dealt with in previous permitting processes through avoidance and mitigation. For the most part, these results imply that more detailed evaluation will be necessary during any permit application process that involves public water supply amounts and distributions similar to those evaluated in these simulations.

SFWMM Incremental Simulations Results

The number of years with water restrictions caused by Lake Okeechobee supply-side management was five for both the 1995 Revised Base Case and 2005 simulations. The number decreases to three for the 2010 simulation and then to two for both the 2015 and LEC-1 Revised simulations. Results for the 1995 Revised Base Case and 2005 simulations indicated that they could not meet a 1-in-10 year level of certainty due to Lake Okeechobee stages. Regional storage in the absence of major water resource development projects, which will not be completed until after 2005, were inadequate. The results for the 2015 and LEC-1 Revised simulations indicated that the projects recommended by the Restudy will provide a 1-in-10 year level of certainty for the four LEC service areas and

LOSA. In the 2005 SSM Scenario, the performance remained the same as the original 2005 simulation. Changes to the supply-side management criteria did not affect the ability to provide regional water to the LEC service areas during a 1-in-10 year drought event.

The information in **Table 22** summarizes the frequency of water shortage declarations due to coastal saltwater intrusion water level criteria. These data are presented for each service area, since water shortage declarations are usually based on local resource conditions.

Table 22. Number of Years with Water Restrictions Caused by Local Triggers in the SFWMM Incremental Simulations for the Lower East Coast Service Areas during the 30 Water Years Simulated.

Service Area	1995 Revised Base Case	2005	2010	2015	LEC-1 Revised
North Palm Beach Service Area	5	1	0	0	0
LECSA 1	7	0	0	0	0
LECSA 2	21	13	8	11	12
LECSA 3	4	5	3	3	2

Table 23 presents tabulations of the number of times water shortages were triggered by local ground water conditions by trigger well locations during each of the simulations. It should be noted, that in all cases, these declarations were for Phase I and Phase II shortages and restrictions that pose an inconvenience to users, but were not likely to result in economic losses. A more detailed discussion of water shortage phases is provided on **pages 25** through **28** in **Chapter 2**.) In all of the simulations, amounts and locations of pumpage significantly affected coastal saltwater intrusion problems. Such problems were solved as soon as the appropriate wellfield distributions or water supply development options were implemented.

1995 Revised Base Case. Water shortage problems were significant in the 1995 Revised Base Case in all service areas except LECSA 3, where regional wellfields have been established inland from areas subject to saltwater intrusion (**Table 23**). Ground water stage monitoring locations in the Tequesta, Jupiter, Lake Worth, Fort Lauderdale Airport, Hollywood, and Homestead areas accounted for most of the shortages. This simulation did not meet the 1-in-10 year level of certainty.

2005. In the 2005 simulation and subsequent incremental simulations, the utility-preferred wellfield distribution, as modified in LEC-1, is applied. In the 2005 simulation, water shortages caused by local triggers were eliminated in LECSA 1 and were greatly reduced in the North Palm Beach Service Area. The number of cutbacks in LECSA 2 was primarily a result of the sensitivity to the assumed location of public water supply withdrawals from the Surficial Aquifer System (SAS). The number of restrictions in LECSA 3 increased slightly when compared to the 1995 Revised Base Case. This may have been due to demand growth, changes in pumpage distribution from the 1995 Revised Base Case, or other factors that affect water levels in areas near the Miami and Cutler Ridge monitoring locations.

Table 23. Number of Times Water Restriction Triggers in the SFWMM Incremental Simulations for the Lower East Coast Service Areas Were Triggered.[a]

Trigger Well	1995 Revised Base Case	2005	2010	2015	LEC-1 Revised
Tequesta	5				
Jupiter	4	1			
Gardens		1			
Lake Worth	11				
Pompano	1				
North Lauderdale	3	5	2	2	3
Lauderdale	4	1			
Fort Lauderdale Airport	27 + (1)	25 + (1)	1	1	1
Hollywood	53 + (3)	21	12	15	17
North Miami Beach	1				
Miami		2			
Cutler Ridge	1	4			
Homestead	5	7	3	3	
Florida City	3	2			
Taylor	3	5	5	5	5

a. Phase 2 in parentheses, all others are Phase 1

2010. The 2010 simulation indicated that the 1-in-10 year level of certainty can be met, based on coastal ground water conditions. No cutbacks due to low ground water levels occurred in the North Palm Beach Service Area or LECSA 1. In LECSA 2, the numbers of restrictions that occurred in the Fort Lauderdale Airport and Hollywood area declined from 2005, probably due to inclusion of the southern portion of the Broward Secondary Canal Recharge System, as recommended in the Restudy. Also, triggering for North Miami Beach, whose wellfield is in LECSA 2, were eliminated. In LECSA 3, triggers in the Miami, Cutler Ridge, and Florida City areas were eliminated while those in the Homestead area were further reduced. These improvements were likely due to the implementation of features recommended in the Restudy and the addition of Miami-Dade County Utility ASR facilities.

2015. As in the 2010, ground water level triggering did not occur in the North Palm Beach Service Area or LECSA 1 in the 2015 simulation. In LECSA 2, some additional triggering occurred in the Hollywood area, probably as a result of demand growth in the area without any infrastructure or wellfield location improvements beyond 2010. Water demands in Hollywood increased slightly from 19.31 MGD in 1995 to 22 MGD in the LEC-1 Revised, while Hallandale, Dania Beach, and Broward 3A were on standby starting in 2005 and withdrawal was relocated to the Broward County South Regional Wellfield. In LECSA 3, triggers in the Homestead area remained the same as in 2010.

LEC-1 Revised. In the LEC-1 Revised simulation, no water shortages occurred due to low ground water levels in the North Palm Beach Service Area or LECSA 1. In LECSA 2, some additional trigger events occurred in the Hollywood area and one additional trigger event occurred in the Lauderdale area compared to 2015. These were also the likely result of demand growth without any additional infrastructure or wellfield location improvements beyond 2010 refinement of the wellfield distribution. In LECSA 3, trigger events in the Homestead area were eliminated and only those in the Taylor area, which are insensitive to public water supply withdrawals remained.

The incremental simulation results indicated that the ability to meet a 1-in-10 year level of certainty improved over time as the Restudy and other water resource development projects were implemented. The volume and location of public water supply withdrawals significantly affected coastal saltwater intrusion. Saltwater intrusion was largely be avoided, and the associated restrictions diminished, when appropriate water supply options such as wellfield relocation, distribution, and operational changes were implemented. In 2005, use of the utility-preferred wellfield distribution (same as LEC-1) solved coastal trigger problems in the North Palm Beach Service Area, LECSA 1, and LECSA 3. The low coastal ground water stages in LECSA 2 were avoided by altering the distribution or allocation of public water supplies year-round or conditionally, depending on the severity and location of low ground water stages. The LEC-1 Revised simulation demonstrated the ability to avoid saltwater intrusion and water restrictions with minor adjustments to public water supply distribution.

Hollywood Seminole Indian Reservation

The Seminole Tribe of Florida is currently reviewing its options to self-supply its Hollywood Seminole Indian Reservation by shifting supply of its public water supply demands to its own utility system. The average and maximum daily demands associated with this facility during the planning horizon are expected to be approximately 1.5 MGD and 2.0 MGD, respectively. The modeling analyses performed to support the LEC regional water supply planning process did not include these demands in the model assumptions, but did evaluate withdrawals on the Hollywood Seminole Indian Reservation at a rate of 0.88 MGD on average. It is staff's opinion that average withdrawals of 1.5 MGD and a maximum daily withdrawal of 2.0 MGD on the Hollywood Reservation are attainable. In addition, the Seminole Tribe has agreed to participate in the Southeast Broward County Interconnected Water Supply System discussions (**Recommendation 8** in **Chapter 6**). These discussions will deal with developing water supply solutions for the water supply utilities of southeast Broward County, while protecting the water rights of the Seminole Tribe.

Summary of Results for the Lower East Coast Service Areas

- The 1995 and 2020 base cases did not meet a 1-in-10 year level of certainty performance.
- The 2020 with Restudy, LEC-1, and LEC-1 Revised model simulations were capable of meeting 2020 water supply projections in the LEC service areas.
- The SFWMM results demonstrated that the frequency of supply-side management restrictions in the 2020 with Restudy, the

LEC-1, and the LEC-1 Revised simulations met the 1-in-10 year level of certainty planning criteria for the LEC service areas.

- The redistribution of wellfield withdrawals in the 2020 with Restudy and the LEC-1 simulations demonstrated the significant effect that wellfield withdrawals had on local ground water conditions and on the ability to meet the 1-in-10 year level of certainty. This is evidenced in southeast and central Broward County, where redistribution of wellfield withdrawals in the model simulations was the determining factor for meeting the 1-in-10 year level of certainty based on local conditions.
- A 1-in-10 year level of certainty for public water supply was not met in the LEC service areas. The subregional ground water model simulations indicated that water shortage restriction criteria were met and harm to wetlands and the Biscayne aquifer were avoided. Implementation of Restudy projects, refinement of utility preferred wellfield distributions and operations, and implementation of water supply development options were necessary to meet the 1-in-10 year level of certainty.
- Assuming the utility-preferred withdrawal locations are implemented as proposed, several public water suppliers may need to implement water supply development options and/or further refine their preferred wellfield locations in order to meet the 1-in-10 year level of certainty. These utilities include Lake Worth, Manalapan, Lantana, Fort Lauderdale, Hallandale, Hollywood, Dania Beach, and Broward County 3A, 3B, and 3C.
- A few utilities may meet a 1-in-10 year level of certainty, but may not meet CUP criteria for wetland drawdowns, and/or avoid saltwater intrusion, unless their wellfield distribution and seasonal operations are refined. These utilities include Seacoast, Jupiter, Riviera Beach, Pompano Beach, Boca Raton's eastern wellfield, Coral Springs, North Springs Improvement District, the proposed Miami-Dade WASD’s proposed south regional wellfield and existing west wellfield, North Miami, North Miami Beach, and Homestead.

ENVIRONMENTAL RESOURCES RESULTS

As with the evaluations of urban areas, two different sets of simulations were performed using the SFWMM. The first set of simulations compares current (1995) and future (2020) base case conditions. A second set of model simulations was created to visualize the incremental changes that occur to the overall system at five-year intervals (2005, 2010, and 2015) as Restudy and other water resource development components come on-line. Detailed descriptions of the parameters, conditions, and rationales used in each model simulation can be found in the **Model Simulations** section of this chapter. An overview of results for each set of simulations is presented first, then performance measures and results for both sets of simulations are discussed by natural area.

District staff have recently developed proposed MFL criteria for three priority water bodies included within the LEC Planning Area (SFWMD, 2000e). These water bodies include Lake Okeechobee, the Biscayne aquifer, and the Everglades. The Everglades includes the WCAs, the Holey Land and Rotenberger WMAs, and the freshwater regions of Everglades National Park. The final draft document proposes minimum water level depths, durations, and frequencies of occurrence that will guide the operation of the C&SF Project and future management of Lake Okeechobee, the Everglades, and the Biscayne aquifer. The ability to achieve these proposed MFL criteria is assessed for each natural area and each set of model simulations.

Overview of Results

Overview of Base Cases and Alternatives Results

Results for the current (1995) and future (2020) base cases were obtained from model simulations for the same conditions that were obtained for the urban areas: 1995 Base Case, 2020 Base Case, 2020 with Restudy, and LEC-1. These conditions were analyzed and the results are displayed in formats similar to the methods that were used for the Restudy, with the addition of the MFL criteria, which were subsequently developed for Lake Okeechobee, the Everglades, and the Biscayne aquifer (SFWMD, 2000e).

Table 24 provides a color-coded evaluation of the overall results of each base case and alternative simulation. The color codes (green, yellow, or red) represent a scoring system to evaluate model output, based on review of key environmental performance measures discussed later in this chapter and in **Appendix D** and use of best professional judgement by District scientists. Similar color-coding schemes and definitions were used in the Restudy to provide a qualitative assessment of the ability of particular water supply actions or features to meet environmental management objectives of this plan.

1995 Base Case. A majority of the natural areas (14 out of 21 areas evaluated) in the 1995 Base Case were scored as red, indicating they did not currently meet LEC environmental planning criteria (**Table 24**). These areas were Lake Okeechobee, the Caloosahatchee and St. Lucie estuaries, Lake Worth Lagoon, Rotenberger WMA, WCA-2B, all of WCA-3 except Indicator Region 17, Shark River Slough, the Rockland marl marsh, western Florida Bay, and Whitewater Bay. Ecosystems will not recover in these areas unless major hydrologic improvements occur. Five areas were scored yellow (**Table 24**), indicating marginal or uncertain ability to meet environmental targets and achieve recovery. These areas were the Holey Land WMA, northern WCA-2A (Indicator Region 25), central WCA-3A (Indicator Region 17), WCA-3B, and central and southern Biscayne Bay. Only three areas were scored green (**Table 24**), indicating that they currently met environmental performance measure targets and will likely result in long-term sustainability of the ecosystem, providing water quality standards are met. These

Table 24. South Florida Water Management Model Results for Base Cases and Alternatives for Natural Areas within the Lower East Coast Planning Area.[a]

Area	Indicator Region(s)[b]	1995 Base Case	2020 Base Case	2020 with Restudy	LEC-1
Lake Okeechobee	NA	R	R	G	G
Caloosahatchee Estuary	NA	R	R	G	G
St. Lucie Estuary	NA	R	R	G	G
Lake Worth Lagoon	NA	R	Y	Y	Y
Loxahatchee National Wildlife Refuge (WCA 1)	27 and 26	G	Y	G	G
WCA-2A	24 and 25	Y/G	Y/G	Y/G	Y/G
WCA-2B	23	R	R	R	R
Holey Land WMA	29	Y	Y	G	G
Rotenberger WMA	28	R	G	G	G
Northwestern WCA-3A	20 and 22	R	G	G	G
Northeastern WCA-3A	21	R	Y	G	G
Eastern WCA-3A	19	R	Y	Y	Y
Central WCA-3A	17 and 18	Y/R	Y/R	G/Y	G/Y
Southern WCA-3A	14	R	R	G	G
WCA-3B	15 and 16	Y	Y	Y	Y
Shark River Slough	9, 10, and 11	R	R	G/Y	G/Y
Rockland Marl Marsh	8	R	R	Y	Y
Northern Biscayne Bay	NA	G	Y	Y	Y
Central Biscayne Bay	NA	Y	Y	Y	Y
Southern Biscayne Bay	NA	Y	Y	Y	G
Western Florida and Whitewater Bays	NA	R	R	G	G

a. G (green) = planning targets met
Y (yellow) = ability to meet targets was marginal or uncertain, or goal was not defined
R (red) = planning targets not met
b. An indicator region is a grouping of model grid cells within the SFWMM that consists of similar vegetation cover and soil type. Indicator regions were used only in simulations for the Everglades.

areas were the Arthur R. Marshall Loxahatchee National Wildlife Refuge (WCA-1), southern WCA-2A (Indicator Region 24), and northern Biscayne Bay.

2020 Base Case. Fewer areas scored red in the 2020 Base Case compared to the 1995 Base Case, but most of the region still did not meet the environmental planning targets (**Table 24**). The 2020 Base Case showed improvement in some areas over the 1995 Base Case. These areas were Lake Worth Lagoon, the Rotenberger WMA, and northeastern, northwestern, and eastern WCA-3A. Lake Worth Lagoon improved due to the capability to store water in STA-1 East, which reduced the amount of water discharged to the lagoon. The Rotenberger WMA and northern WCA-3A improved due to completion of the Everglades Construction Project in 2003. Two areas became worse under the 2020 Base Case, the Arthur R. Marshall Loxahatchee National Wildlife Refuge (WCA-1) and northern Biscayne Bay, changing from green to yellow.

2020 with Restudy and LEC-1. Results show that the 2020 with Restudy and LEC-1 simulations performed very similar to each other (**Table 24**) and provided significant hydrological improvements to the regional ecosystem. Significant and substantial progress was made in these alternatives toward meeting environmental restoration targets for the Everglades and the estuaries. Overall, 14 out of 21 sites scored green under the LEC-1 and 2020 with Restudy alternatives, indicating they met LEC water supply planning targets and will likely result in recovery and long-term sustainability of the ecosystem, providing water quality standards are met. These areas were Lake Okeechobee, the St. Lucie and Caloosahatchee estuaries, the Holey Land and Rotenberger WMAs, Arthur R. Marshall Loxahatchee National Wildlife Refuge (WCA-1), northern WCA-2A (Indicator Region 25), northeastern and northwestern WCA-3A, a portion of central WCA-3A (Indicator Region 17), southern WCA-3A, western Florida Bay, and Whitewater Bay. These alternatives show great improvement relative to the 1995 and 2020 base cases. Shark River Slough scored green/yellow, which was an improvement relative to the base cases, but did not perform quite as well as Alternative D13R in 2050, when all of the Restudy projects were completed (USACE and SFWMD, 1999).

Areas that indicated marginal or uncertain ability to meet the environmental objectives of the LEC Plan (scored yellow) and need further improvement, or where the target was not yet defined, include Lake Worth Lagoon, southern WCA-2A (Indicator Region 24), eastern WCA-3A (Indicator Region 19), a portion of central WCA-3A (Indicator Region 18), WCA-3B, the Rockland marl marsh located within Everglades National Park, and northern and central Biscayne Bay (**Table 24**). These results were very similar to those achieved under Alternative D13R, with the Restudy projects completed by 2050 (USACE and SFWMD, 1999).

Only one area, WCA-2B, was scored red for the 2020 with Restudy and LEC-1 alternatives (**Table 24**). These results indicated that environmental planning targets will not be met, ecosystem recovery will not likely occur, and WCA-2B will need improvements. Again, these results were similar to results from the Restudy model simulations for this area. However, LEC-1 showed improved performance as compared to Alternative D13R (USACE and SFWMD, 1999).

Overview of Incremental Modeling Results for Natural Areas

Table 25 provides a color-coded evaluation of the overall results of each incremental simulation based on a review of key performance measures discussed later in this chapter and in **Appendix D**. Lake Okeechobee and the St. Lucie and Caloosahatchee estuaries showed improvements by 2010, and met their respective planning targets by 2015. These improvements were due in part to the construction of regional reservoirs within the C-43 and C-44 basins. Similar improvements occurred over time in the Arthur R. Marshall Loxahatchee National Wildlife Refuge, northern WCA-3A, and the Holey Land and Rotenberger WMAs. These areas met proposed planning targets during the 2010 simulation as a result of completion of the Everglades Construction Project and the EAA Storage Reservoirs, and implementation of rain-driven water deliveries for the WCAs. In contrast, performance measure targets were not met in central and southern WCA-3A and WCA-3B until the LEC-1 Revised simulation (2020).

Table 25. South Florida Water Management Model Results for Incremental Simulations for Natural Areas within the Lower East Coast Planning Area.

Area	Indicator Region(s)[a]	1995 Revised Base Case	2005	2010	2015	LEC-1 Revised	D13[b]
Lake Okeechobee	NA	R/Y	Y	Y	G	G	G
Caloosahatchee Estuary	NA	R	R	Y	G	G	G
St. Lucie Estuary	NA	R	R	Y	G	G	G
Lake Worth Lagoon	NA	R	R	Y	Y	Y	Y
Loxahatchee National Wildlife Refuge (WCA 1)	27 and 26	G	G/Y	G	G	G	G
WCA-2A	24 and 25	G/Y	G/Y	G/Y	G/Y	G/Y	G/Y
WCA-2B	23	R	R	R	R	R	R
Holey Land WMA	NA	R	R	G	G	G	G
Rotenberger WMA	NA	R	Y	G	G	G	G
Northwestern WCA-3A	20 and 22	R	Y	G	G	G	G
Northeastern WCA-3A	21	R	G	G	G	G	Y
Eastern WCA-3A	19	R	Y	Y	Y	Y	Y
Central WCA-3A	17 and 18	Y/R	G/Y	G/Y	G/Y	G/Y	G/Y
Southern WCA-3A	14	R	Y	Y	Y	G	G
WCA-3B	15 and 16	Y	Y	Y	Y	Y/G	Y
Shark River Slough	9, 10, and 11	R	R	R/Y	Y	G/Y	G
Rockland Marl Marsh	8	R	Y	Y	Y	Y	Y
Northern Biscayne Bay	NA	G	Y	G	G	Y	G
Central Biscayne Bay	NA	Y	Y	Y	Y	Y	G
Southern Biscayne Bay	NA	Y	Y	Y	Y	G	G
Western Florida and Whitewater Bays	NA	R	Y	Y	Y	G	G

a. An indicator region is a grouping of model grid cells within the SFWMM that consists of similar vegetation cover and soil type. Indicator regions were used only in simulations for the Everglades.
b. D13 is short for Alternative D13, a simulation performed for the Restudy (USACE and SFWMD, 1999).

Incremental modeling results for Everglades National Park showed a gradual improvement in the ability to attain flow targets. Beginning with the 2005 simulation, the distribution and volume of water provided to northeastern and northwestern Shark River Slough significantly improved. During the 2010 simulation substantial improvements in meeting NSM hydroperiod targets were recorded in northeastern and central Shark River Slough, with nearly full achievement of the target during the LEC-1 Revised simulation (100 percent of the slough matches the NSM hydroperiod target during the LEC-1 Revised simulation). In the Rockland marl marsh, significant hydroperiod improvements were first noted during the 2005 simulation within this overdrained area of the park and continued through the LEC-1 Revised simulation. These improvements appear to be linked to the construction of the Lake Belt Project (which is expected to be only 50 percent complete by 2020) and full implementation of Lake Okeechobee ASR, which will free up water that can be delivered downstream from the lake to Everglades National Park. These results showed the importance of the Lake Belt Project, which will have large water storage reservoirs to capture and store water during wet periods and deliver it to Everglades National Park with the proper timing and volumes to hydrologically restore this area.

A number of areas did not fully meet the planning targets and were scored as yellow or red (**Table 25**). One area, WCA-2B, was scored red in the LEC-1 Revised Simulation, indicating that it did not meet planning targets and was in need of major improvement. Areas that scored yellow (exhibited marginal or uncertain performance) in LEC-1 Revised Simulation included the Lake Worth Lagoon, southern WCA-2A (Indicator Region 24), northeastern (Indicator Region 21) and eastern (Indicator Region 19) WCA-3A, a portion of central WCA-3A (Indicator Region 18), a portion of Shark River Slough (Indicator Region), the Rockland marl marsh located within Everglades National Park, and northern and central Biscayne Bay. These results were similar to the findings presented by the Restudy, which identified problems in meeting proposed environmental targets for these areas by 2050 (USACE and SFWMD, 1999).

Lake Okeechobee

Extreme fluctuations of both high and low water levels within Lake Okeechobee over the past two decades have had major adverse impacts on water quality, the distribution of littoral zone vegetation communities that support fish and wildlife habitat, and downstream estuaries which receive regulatory releases from the lake. The following set of performance measures were developed to judge how well each water supply alternative reduces the frequency of these extreme high and low water events and improves the overall ability of the regional ecosystem to meet the environmental objectives of the LEC Plan.

Performance Measures Applied

Performance measures and hydrologic targets developed for Lake Okeechobee are listed below. These performance measures are similar to those used in the Restudy and that were developed by Havens and Rosen (1995). These two references provide the background information and rationale for development of the following five priority performance measures for Lake Okeechobee, which were used to evaluate the lake:

- Number of times lake stages exceeded 17 ft NGVD for more than 50 days
- Number of times lake stages exceeded 15 ft NGVD for more than one year
- Number of times lake stages fell below 12 ft NGVD for more than one year
- Number of times lake stages fell below 11 ft NGVD
- Number of spring water level recessions, i.e., the number of times between the months of January and March that lake stages declined from near 15 to 12 ft NGVD (these conditions are judged as favorable for wading bird foraging and nesting and other water-dependent wildlife present within the littoral zone)

Base Cases and Alternatives Results

Table 26 provides an evaluation of the lake under the 1995 and 2020 base cases as compared to the 2020 with Restudy and LEC-1 simulations.

Table 26. Summary of Base Case and Alternative Modeling Results for Lake Okeechobee Priority Performance Measures.

Priority Performance Measures	1995 Base Case	2020 Base Case	2020 with Restudy	LEC-1
Number of times stages exceeded 17 ft NGVD for more than 50 days	4	2	2	2
Number of times stages exceeded 15 ft NGVD for more than one year	4	1	1	1
Number of times stages fell below 12 ft NGVD for more than one year	1	2	1	1
Number of times stages fell below 11 ft NGVD	4	19	4	4
Number of spring water level recessions[a]	5	4	9	8

a. Number of years during the months of January-May that lake levels declined from near 15 to 12 ft NGVD (without a water level reversal greater than 0.5 feet). These conditions are judged as favorable for wading bird foraging and nesting and also benefit other wildlife species present within the marsh. These water level recessions are also beneficial for reestablishment of willow stands and also allow fire to burn away cattail thatch (Havens et al., 1998).

1995 Base Case. The 1995 Base Case had the largest number of extreme high water events (number of times stages exceeded 17 ft NGVD for more than a 50-day duration) that impacted the littoral zone, increased the frequency that large volumes of water were discharged to downstream estuaries, and increased the risk of flooding of lakeside communities. In addition, the number of times that the littoral zone was flooded for long periods of time (number of times lake stages exceeded 15.0 ft NGVD for more than one year) was greater than the numbers that occurred during the future water supply simulations. In contrast, fewer extreme low water events (number of times lake stages fell below 11 and 12 ft NGVD) that dried out the marsh and impacted the ability of the lake to provide water supply for the LEC Planning Area occurred under the 1995 Base Case than under the future simulations (**Table 26**). The lake also had relatively fewer occurrences of favorable spring water level recessions that benefit wading bird and snail kite foraging and nesting as compared to the 2020 with Restudy and the LEC-1 (**Table 26**).

2020 Base Case. Increased water demands under the 2020 Base Case led to a significant increase in the number of times lake levels fell below 11 ft NGVD as compared to the 1995 Base Case (19 times versus four times). This increase in low water periods had the potential to dry out the marsh more often and impact water supplies. The 2020 Base Case showed an improvement in reducing the number of times that extreme high water conditions occurred during the 31-year simulation period when compared to the 1995 Base Case (**Table 26**). Although lake dry downs occurred more often under the 2020 Base Case than under the 1995 Base Case, they did not appear to coincide with the spring water level recessions preferred by wading birds and other water-dependent species.

2020 with Restudy and LEC-1. The 2020 with Restudy and LEC-1 alternatives both performed significantly better than the base cases to meet the five priority performance measures for Lake Okeechobee (**Table 26**). The most dramatic improvement occurred in terms of the reduced number of extreme low lake stage events (i.e., lake stages which receded below 11 ft NGVD and completely dried out the littoral zone). Review of stage duration curves also showed improved hydrologic conditions within the littoral zone for the 2020 with Restudy and LEC-1 alternatives.

Littoral Zone Impacts. Under the 1995 Base Case simulation, the littoral zone was flooded 37 percent of the time during the 31-year simulation period. These results were similar to current conditions on the lake, which have resulted in prolonged flooding of the littoral zone and loss of beneficial littoral zone plant communities in favor of introduced exotics (e.g., torpedo grass), as well as impacts to wading birds and other water-dependent wildlife. High lake stages have also been associated with increased in-lake nutrient loading, turbidity, and increased frequency of blue-green algal blooms (SFWMD, 1997).

Long-term flooding of the littoral zone was reduced significantly under the 2020 Base Case, 2020 with Restudy, and LEC-1 alternatives, which exhibited littoral zone flooding for 21, 18, and 16 percent of the time, respectively, during the 31-year simulation period. This was a major improvement over the 1995 Base Case condition. Although each of these simulations resulted in a lower number of damaging high water events compared to the 1995 Base Case, only the 2020 with Restudy and LEC-1 alternatives showed improved hydrologic benefits at both ends of the hydrograph (**Appendix H**).

Minimum Flows and Levels. Minimum water level criteria were met for Lake Okeechobee under the 1995 Base Case, 2020 Base Case, 2020 with Restudy, and LEC-1 simulations (**Table 27**). Best results occurred under the 1995 Base Case, 2020 with Restudy, and LEC-1 simulations, which met the criteria by a wide margin. Water levels fell below 11 ft NGVD for greater than 80 days only twice (once every 15 years) during the 31-year simulation period. In contrast, increased water use demands in the 2020 Base Case caused water levels to dropped below 11 ft NGVD for more than an 80-day duration a total of five times (once every six years) during the 31-year simulation period. These results were just within the limits of meeting the proposed MFL criteria for Lake Okeechobee.

Table 27. The Ability of Base Case and Alternative Simulations to Meet Proposed Minimum Water Level Criteria[a] for Lake Okeechobee for the 31-Year Simulation Period.

Performance Measure	1995 Base Case	2020 Base Case	2020 with Restudy	LEC-1
Number of times water levels fell below 11 ft NGVD for more than 80 days duration	2 (1-in-15 years)	5 (1-in-6 years)	2 (1-in-15 years)	2 (1-in-15 years)

a. MFL Planning Target = water levels should not fall below 11 ft NGVD for more than 80 days, no more often than once every six years

Incremental Simulations Results

Hydrologic Performance. Table 28 provides a summary of the ability of the incremental simulations to meet the five priority performance measures developed for Lake Okeechobee. The incremental modeling simulations shown in **Table 28** included the WSE schedule for Lake Okeechobee. Implementation of the WSE under the 1995 Revised Base Case showed an improvement in reducing the number of times lake stages exceeded 17 ft NGVD when compared to the 1995 Base Case (**Table 26**). This reduction in the number of extreme high water events should help protect the ecosystem from the effects of damaging high water levels that impact the littoral zone and increase the risk of flooding.

In the incremental simulations, the number of times water levels fell below 11 ft NGVD were reduced (**Table 28**), which helped protect the littoral zone and increased the District's ability to protect the Biscayne aquifer against saltwater intrusion during dry periods. This was the result of new regional reservoirs coming on-line in 2010, 2015, and 2020, and implementation of the Lake Okeechobee ASR, which helped decrease demands on the lake during dry periods.

Table 28. Summary of Incremental Modeling Results for Lake Okeechobee Priority Performance Measures.

Priority Performance Measure	1995 Revised Base Case	2005	2005 SSM Scenario	2010	2015	LEC-1 Revised
Number of times stages exceeded 17 ft NGVD for more than 50 days	2	2	2	1	2	2
Number of times stages exceeded 15 ft NGVD for more than one year	3	3	3	2	2	1
Number of times stages fell below 12 ft NGVD for more than one year	1	1	1	1	1	1
Number of times stages fell below 11 ft NGVD	8	12	11	9	5	3
Number of spring water level recessions[a]	5	5	5	5	6	10

a. Number of years during the months of January-May that lake levels declined from near 15 to 12 ft NGVD (without a water level reversal greater than 0.5 feet). These conditions are judged as favorable for wading bird foraging and nesting and also benefit other wildlife species present within the marsh. These water level recessions are also beneficial for reestablishment of willow stands and also allow fire to burn away cattail thatch (Havens et al., 1998).

The number of spring water level recessions increased during the LEC-1 Revised simulation. The timing of these water level recessions was favorable for wading bird foraging and nesting and also provided benefits to other water-dependent wildlife present within the littoral zone.

Comparison of the 2005 incremental simulation versus the 2005 SSM Scenario showed only minor differences in performance for Lake Okeechobee. The primary difference was that under the 2005 SSM Scenario, slightly less water was available in the lake during dry periods. However, this difference was not enough to exceed proposed MFL criterion for the lake (**Table 29**). Review of the five priority performance measures developed for Lake Okeechobee showed very similar performance for both simulations. Results from the 2005 incremental simulation and the 2005 SSM Scenario are presented in **Table 28**.

Minimum Flows and Levels. The water supply planning MFL criterion for the lake is as follows: water levels should not fall below 11 ft NGVD greater than 80 days, no more often than once every six years on average. **Table 29** presents incremental modeling results that describe how well the proposed MFL criterion were met over the 20-year planning period. These values were well within the range of the proposed MFL target for Lake Okeechobee. The MFL planning target was not met only five times during the 31-year simulation period.

Table 29. Lake Okeechobee Minimum Flows and Levels Incremental Results for the 31-Year Simulation Period.

MFL Criterion	Target	1995 Revised Base Case	2005	2005 SSM Scenario	2010	2015	LEC-1 Revised
Number of times lake stages fell below 11 ft NGVD for more than 80 days	5 (1-in-6 years)	2 (1-in-15 years)	2 (1-in-15 years)	4 (1-in-8 years)	3 (1-in-10 years)	2 (1-in-15 years)	1 (1-in-30 years)

St. Lucie and Caloosahatchee Estuaries

Large releases of fresh water discharged from Lake Okeechobee and the associated local canal watersheds have contributed to poor water quality conditions and caused wide fluctuations of salinity to occur within both the St. Lucie and Caloosahatchee River estuaries. These high volume discharge events have increased turbidity, caused color problems, reduced light penetration, and created salinity conditions that are too low to support important estuarine species (e.g., oysters). During high rainfall years, maximum mean monthly flows occasionally exceed 5,000 cfs for the St. Lucie Estuary and 7,000 cfs for the Caloosahatchee Estuary, causing each system to become entirely fresh water. These low salinity conditions result in death of benthic invertebrates, displacement of other estuarine species, and adverse impacts on aquatic productivity within these systems and adjacent waters of the Indian River Lagoon, San Carlos Bay, the Gulf of Mexico, and the Atlantic Ocean. Continuation of the present flow regime will not allow reestablishment of important benthic communities and submerged aquatic vegetation within the inner estuaries. In addition to the damaging effects of these high volume discharge events, estuarine productivity has also been impacted by long-term freshwater discharges that cause sustained, low salinity conditions throughout the estuary.

Another important consideration is the maintenance of base flows to these estuaries during dry periods. Chamberlain et al. (1995) reported salinities greater than 50 percent seawater (17 ppt) within the upper Caloosahatchee Estuary during prolonged low flow conditions. Similarly, relatively high salinity conditions, up to 80 percent of seawater (28 ppt), periodically occur in the St. Lucie Estuary. These relatively high salinity conditions (for an estuary) result in stress to estuarine organisms and reduction of their populations due to increased predation and parasites. The dry season, low flow criteria used in this analyses for the St. Lucie and Caloosahatchee estuaries represent preliminary attempts to establish MFL criteria and performance measures for these systems. District staff are continuing efforts to develop science-based minimum flow criteria for the Caloosahatchee and St. Lucie estuaries that are expected to be completed in 2000 and 2001, respectively.

St. Lucie Estuary

Performance Measures Applied

Three performances measures were developed to help evaluate SFWMM model results for the St. Lucie Estuary:

- Number of times mean monthly flow exceeds 3,000 cfs (high discharge criteria) as compared to target flow criteria
- Number of times mean monthly flow exceeds 2,000 cfs (recommended estuary protection criteria) as compared to target flow
- Number of months that low flow criteria were not met (flows less than 350 cfs from Lake Okeechobee and the C-44 Basin)

Base Cases and Alternatives Results

1995 Base Case. High lake stages and runoff from local basins result in an increased number of times that large volumes of fresh water are discharged to the St. Lucie Estuary. Under the 1995 Base Case, the estuary experienced a high discharge event (mean monthly flows greater than 3,000 cfs) approximately once every year on average during the 31-year simulation (**Table 30**). Fresh water releases of this magnitude resulted in the entire inner estuary becoming fresh water for one month or longer. These types of high volume releases have a major impact on maintaining the estuary's salinity regime, produce poor water quality, and significantly impact estuarine biota.

2020 Base Case. Increased water demands on Lake Okeechobee in 2020 resulted in reduced numbers of high volume releases to the estuary, but did not significantly improve the number of times estuarine protection criteria (mean monthly flow greater than 2,000 cfs) were exceeded (**Table 30**). This was an improvement over the 1995 Base Case, but was still far from the preferred management target.

2020 with Restudy and LEC-1. The number of high volume discharge events (mean monthly flows greater than 3,000 cfs) which impact the estuary was reduced by more than two-thirds compared to the 1995 Base Case and represents a major

Table 30. Number of Times Discharge Criteria Were Exceeded for the St. Lucie Estuary During the 31-Year Simulation Period.

Performance Measure	Target	1995 Base Case	2020 Base Case	2020 with Restudy	LEC-1
Number of times mean monthly flow exceeded 3,000 cfs (high discharge criteria)	5	30	19	8	8
Number of times mean monthly flows exceeded 2,000 cfs (recommended salinity envelop criteria)	23	60	56	27	28
Number of months that low flow criteria were not met (flows less than 350 cfs)	178	150	158	51	127

improvement in hydrologic performance. Both the 2020 with Restudy and LEC-1 model simulations almost met proposed performance targets for the St. Lucie Estuary (**Table 30**). Under these two simulations, mean monthly flows greater than 3,000 cfs (maximum discharge volumes) were exceeded only eight times during the 31-year simulation period, compared to 30 times for the 1995 Base Case and 19 times for the 2020 Base Case.

The 2020 with Restudy and LEC-1 alternatives had fewer times when the recommended salinity envelope was exceeded (i.e., mean monthly flow volumes greater than 2,000 cfs). The 2020 with Restudy and LEC-1 model simulations showed only 27 and 28 instances of the criteria being exceeded, respectively, during the 31-year simulation as compared to 60 events for the 1995 Base Case and 56 events for the 2020 Base Case. The recommended low flow criteria were met for the estuary during all simulations (**Table 30**).

Incremental Results

The number of high discharge events and the number of times proposed estuary protection criteria were exceeded for the St. Lucie Estuary were gradually reduced over time (**Table 31**). Significant reductions in these performance measures first appeared in the 2010 simulation, as a result of construction of regional storage reservoirs within the C-44 (St. Lucie) Basin, and showed continued improvement in the 2015 and LEC-1 Revised simulations. Likewise, the number of times proposed estuary protection criteria were exceeded for the estuary also showed improvement by 2010 for the same reasons. Incremental results also showed that estuary low flow targets were met for all years as shown in **Table 31**. Overall, these values were close enough to meeting the environmental performance measure targets developed for the estuary to be scored as green in **Table 25**.

Caloosahatchee Estuary

Performance Measures Applied

Three performances measures were developed to help evaluate SFWMM model results for the Caloosahatchee Estuary:

Table 31. Number of Times Discharge Criteria Were Exceeded for the 31-Year Simulation Period in the Incremental Simulations for the St. Lucie Estuary.

Performance measure	Target	1995 Revised Base Case	2005	2010	2015	LEC-1 Revised
Number of times mean monthly flows exceeded 3,000 cfs (high discharge criteria)	5	22	21	12	8	8
Number of times mean monthly flows exceeded 2,000 cfs (estuary protection criteria)	23	61	56	38	28	29
Number of times low flow criteria were not met (flows less than 350 cfs)	178	146	156	127	128	127

- Number of times mean monthly flow exceeded 4,500 cfs (high discharge criteria) as compared to target flow criteria
- Number of times mean monthly flow exceeded 2,800 cfs (recommended estuary protection criteria) as compared to target flow
- Number of months that low flow criteria were not met (flows less than 300 cfs from Lake Okeechobee and the C-43 Basin)

Base Cases and Alternatives Results

1995 Base Case. Results for the 1995 Base Case were similar to those observed for the St. Lucie Estuary. High lake stages and runoff from local basins resulted in an increased number of times that large volumes of fresh water were discharged to the Caloosahatchee Estuary. For the 1995 Base Case, the estuary experienced 36 high discharge events (mean monthly flows greater than 4,500 cfs) as compared to the target of only six events during the 31-year simulation period (**Table 32**). Freshwater releases of this magnitude resulted in the entire inner estuary becoming fresh water for one month or longer. These high volume releases had a major impact on maintaining the estuary's salinity regime, resulted in poor water quality, and impacted estuarine biota.

2020 Base Case. Increased water demands on Lake Okeechobee in 2020 reduced the number of high volume releases to the Caloosahatchee Estuary (28 events) and slightly reduced the number of times estuarine protection criteria (mean monthly flow greater than 2,800 cfs) were exceeded as compared to the 1995 Base Case (**Table 32**). This was an improvement over the 1995 Base Case, but was still far from the recommended target.

2020 with Restudy and LEC-1. Under these two water supply alternatives, mean monthly flows greater than 4,500 cfs (maximum discharge volumes) were exceeded only four times for the 2020 with Restudy and eight times for the LEC-1, as compared to 36 times for the 1995 Base Case and 28 times for the 2020 Base Case. This represented a major improvement in hydrologic performance for the Caloosahatchee Estuary. The 2020

Table 32. Number of Times Discharge Criteria Were Exceeded for the Caloosahatchee Estuary During the 31-Year Simulation Period.

Performance Measure	Target	1995 Base Case	2020 Base Case	2020 with Restudy	LEC-1
Number of times mean monthly flow exceeded 4,500 cfs (high discharge criteria)	6	36	28	4	8
Number of times mean monthly flows exceeded 2,800 cfs (recommended salinity envelop criteria)	23	76	67	12	28
Number of months that low flow criteria were not met (flows less than 300 cfs)	60	105	109	36	36

with Restudy performed better than the recommended target for the estuary, while LEC-1 came close to meeting the target (**Table 32**). The 2020 with Restudy and LEC-1 alternatives also produced fewer numbers of times when the recommended salinity envelope was exceeded (mean monthly flow volumes greater than 2,800 cfs). These two water supply alternatives resulted in only 12 and 28 failures to met the criteria, respectively, during the 31-year simulation as compared to 76 events for the 1995 Base Case and 67 events for the 2020 Base Case. Both the 2020 with Restudy and LEC-1 alternatives meet or performed better than the proposed low flow target.

Incremental Results

Incremental modeling results for the Caloosahatchee Estuary were similar to those recorded for the St. Lucie Estuary. The number of high discharge events and the number of times proposed estuary protection criteria were exceeded for the Caloosahatchee Estuary were gradually reduced over time (**Table 33**). Significant reductions in the number of high discharge events first appeared in the 2010 simulation, as a result of construction of regional storage reservoirs within the C-43 (Caloosahatchee) Basin, and showed continued improvement in the 2015 and LEC-1 Revised simulations. Likewise, the number of times proposed estuary protection criteria were exceeded also showed improvement in the 2010 simulation for the same reasons. Estuary low flow targets were met for the incremental simulations (**Table 33**). Overall, these values met the environmental performance measure targets developed for the Caloosahatchee Estuary and were, therefore, scored green (**Table 25**).

Table 33. Number of Times Discharge Criteria Were Exceeded for the 31-Year Simulation Period in the Incremental Simulations for the Caloosahatchee Estuary.

Performance measure	Target	1995 Revised Base Case	2005	2010	2015	LEC-1 Revised
Number of times mean monthly flows exceeded 4,500 cfs (high discharge criteria)	6	33	29	13	9	8
Number of times mean monthly flows exceeded 2,800 cfs (estuary protection criteria)	22	77	64	32	31	29
Number of times low flow criteria were not met (flows < 300 cfs from Lake Okeechobee and the C-43 Basin)	60	146	153	76	36	36

Lake Worth Lagoon

The Lake Worth Lagoon is located along one of the most heavily urbanized areas of the LEC Planning Area. Historically, the lagoon has been subject to inlet and channel dredging, shoreline bulkhead construction, draining and filling of adjacent wetlands, causeway and bridge construction, dock and marina development, industrial and sewage waste disposal, power plant operations, and storm water runoff from three major South Florida drainage canals (C-51/S-155, C-15/S-40, and C-16/S-41). In general terms, problems associated with Lake Worth Lagoon are similar to those experienced in other estuaries within the planning area. During high rainfall periods, large volumes of poor quality water are discharged into the lagoon from drainage basins located more than 20 miles west of the lagoon (e.g. C-51 Basin). These high discharge periods deposit large amounts of suspended solids and produce major impacts to both water quality and the salinity regime of the inner lagoon. While the cumulative impacts of these activities have significantly altered the character of the lagoon and diminished its value as a healthy estuarine ecosystem, it still supports a number of important natural resources and recreational values that should be protected.

Performance Measures Applied

Two performances measures were developed to help evaluate SFWMM model results for the Lake Worth Lagoon:

- The number of times a 14-day moving average discharges from C-15, C-16, and C-51 canals exceeds 500 cfs during the 31-year simulation period was calculated. Preliminary modeling results obtained from Palm Beach County Department of Resource Management (DERM) indicates that flow discharges from the C-51 Canals within the range of 500 cfs was roughly equivalent to a salinity of about 23 ppt within the lagoon under steady state conditions.
- The average annual wet and dry season flows delivered to the Lake Worth Lagoon via C-51/S-155, C-15/S-40 and C-16/S-41 during the 31-year simulation period was calculated.

Base Cases and Alternatives Results

1995 and 2020 Base Cases. Under current (1995 Base Case) conditions the lagoon experienced a high number of high volume discharge events with 308 months during the 31-year simulation period exceeding 500 cfs (**Table 34**). Large volumes of poor quality water were discharged to the lagoon from upstream basins that drain urban and residential developments. These high volume discharge events impacted both water quality and the salinity regime of the inner lagoon. Under the 2020 Base Case, the numbers of high discharge events were reduced by approximately 26 percent due, in part, to increased regional water supply demands and completion of STA-1 East as part of the Everglades Construction Project. The STA-1 East Project includes facilities to divide the C-51 Basin and pump water to the west from developed areas within western Palm Beach

County (known as the Acreage), Royal Palm Beach, and Wellington into the STA-1 East Impoundment for treatment and eventual discharge into WCA-1.

2020 with Restudy and LEC-1. High volume discharge events were reduced even further under the 2020 with Restudy and LEC-1 alternatives to only 114 and 109 high discharge events, respectively, during the 31-year simulation period. These represented 63 and 65 percent reductions, respectively, over the 1995 Base Case (**Table 34**). Reductions in discharges occurred primarily due to a number of water capturing features of the Restudy which routed water away from the lagoon and directed it west and south to the Everglades and other urban areas where water was needed. Because the Lake Worth Lagoon does not currently have an established, science-based flow/ salinity target, it is uncertain whether reductions in flows of this magnitude will have the desired results. For this reason District staff scored this area as yellow (**Table 25**), since it is uncertain whether planning targets can or cannot be met under these two simulations.

Table 34. Number of Times Discharge Criteria Were Exceeded for the Lake Worth Lagoon During the 31-Year Simulation Period.

Performance Measure	1995 Base Case	2020 Base Case	2020 with Restudy	LEC-1
Number of months 14-day moving average flows exceeded 500 cfs	308	228	114	109
Mean annual wet and dry season flows discharged to the lagoon from S-155, S-40, and S-41	561	425	258	252

Incremental Results

Implementation of the STA-1 East Project reduced high volume discharges to the lagoon as early as 2005. These improvements gradually increased over time and by 2020 the total number of times flows exceeded the 500-cfs target was reduced by 65 percent and the total volume of water discharged to the lagoon as storm water runoff was reduced by 51 percent (**Table 35).**

Table 35. Number of Times Discharge Criteria Were Exceeded During the 31-Year Simulation Period in the Incremental Simulations for the Lake Worth Lagoon.

Performance Measure	1995 Revised Base Case	2005	2010	2015	LEC-1 Revised
Number of months that 14-day moving average flows exceeded 500 cfs	304	225	200	98	105
Mean annual wet and dry season flows discharged to the Lake Worth Lagoon from S-155, S-40, and S-41	556	427	395	227	241

Because a clearly defined environmental target has not yet been developed for the Lake Worth Lagoon, this area was scored yellow, indicating that it is uncertain whether flow reductions of these magnitudes will benefit the ecosystem. As part of the LEC Interim Plan, a contract has been funded to work with Palm Beach County DERM to determine both minimum and maximum flow targets for the major canals that discharge into the lagoon. This work is currently under way and should be completed within the next two years.

Results for the Lake Worth Lagoon may need to be reevaluated in future planning efforts. The physical location of the S-155A structure varies from its location in the SFWMM. It was modeled further east than its actual location, and therefore, the model may underestimate flows to the lagoon. In addition, flows from C-17/S-44 need to be considered in the evaluation.

The Everglades

Performance Measures Applied

Performance measures for the Everglades were created with the intent of restoring the essential hydrological features of the natural system that existed prior to drainage and development of the region. Most of the performance measures used in this evaluation are similar to those used by the Restudy, with addition of MFL criteria for Lake Okeechobee, the Everglades, and the Biscayne aquifer. These performance measures were used to evaluate each model simulation's potential to (1) protect and support accretion of peat and marl soils, (2) protect tree island communities, and (3) maintain Everglades sawgrass or ridge and slough communities. The majority of performance measure targets for the Everglades were based on restoring the hydrological pattern predicted by the Natural System Model version 4.5 Final (NSM), with a few exceptions. The performance measures applied are as follows:

- Ability to meet the Everglades minimum water level criteria presented in **Table 44** (SFWMD, 2000e)
- Ability to meet NSM-defined surface water inundation/duration patterns, where appropriate
- Number and duration of extreme high and low water events
- Interannual depth variation (average and standard deviation of water depths for the months of May and October for the 31-year simulation period)
- Temporal variation in mean weekly stage
- Review of stage hydrographs and stage duration curves

More detailed descriptions of these performance measures and their associated targets can be found in **Appendix D** of this document.

Overview of Everglades Results

Model results for each alternative were evaluated at the level of individual indicator regions. An indicator region is a grouping of model grid cells within the SFWMM that consists of similar vegetation cover and soil type. These larger groupings of cells were developed to reduce the uncertainty of evaluating results from a single two-by-two square mile grid cell that represents a single water management gage or area. **Figure 27** shows the location of each indicator region evaluated in this study.

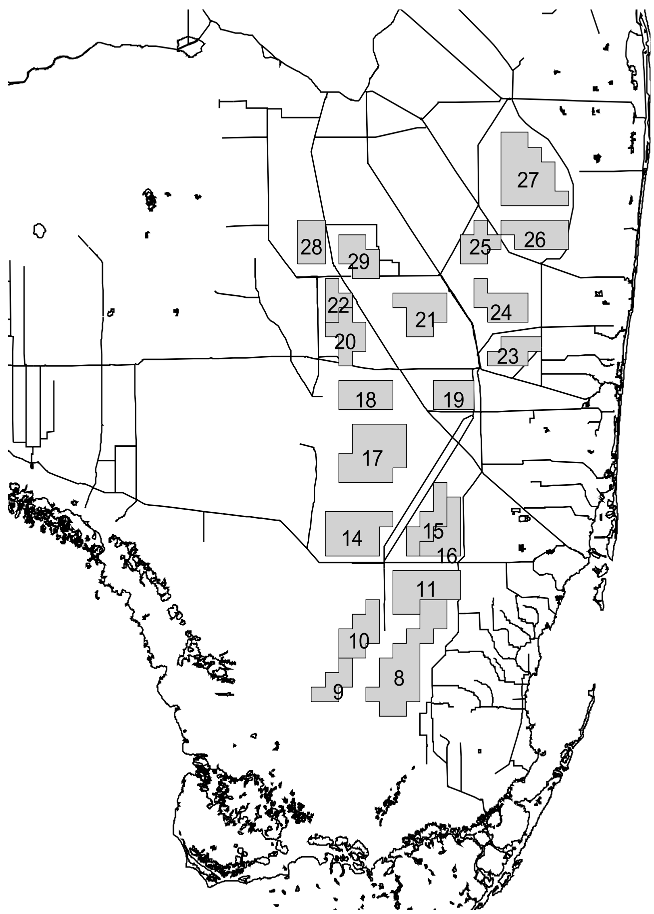

Figure 27. Everglades Indicator Regions used in the Analysis of Model Run Alternatives.

For final analyses, indicator regions that fell within areas of similar hydrological conditions or within the same impoundment system were grouped together. The final evaluation classified the indicator regions into 11 hydrological subregions of the Everglades:

- Arthur R. Marshall Loxahatchee National Wildlife Refuge (WCA-1): Indicator Regions 26 and 27
- Holey Land and Rotenberger WMAs: Indicator Regions 29 and 28

- WCA-2A: Indicator Regions 24 and 25
- WCA-2B: Indicator Region 23
- Northern WCA-3A: Indicator Regions 20, 21, and 22
- Eastern WCA-3A: Indicator Region 19
- Central WCA-3A: Indicator Regions 17 and 18
- Southern WCA-3A: Indicator Region 14
- WCA-3B: Indicator Regions 15 and 16
- Shark River Slough: Indicator Regions 9, 10, and 11
- Rockland marl marsh: Indicator Region 8

The results of the base case and alternative simulations are presented by indicator region in **Tables 36**, **37**, and **38**. Results of the incremental simulations (2005, 2010, 2015, and LEC-1 Revised) are presented in **Tables 39**, **40**, and **41**. These tables present several types of data: duration of average annual flooding (**Tables 36** and **39**); the number of weeks that water levels were below the low water depth criteria (**Tables 37** and **40**); and the number of weeks the high water depth criteria were exceeded (**Tables 38** and **41**). Results will be discussed in detail by hydrological subregion. Graphical depictions of the results can be found in **Appendix H**.

Table 36. Duration of Average Annual Flooding in the Base Case and Alternative Simulations for the Everglades.[a]

Area Name	Indicator Region	Percent of Year				
		NSM	1995 Base Case	2020 Base Case	2020 with Restudy	LEC-1
Northern WCA-1	27	92	97	92	96	96
Southern WCA-1	26	89	99	96	99	100
Northern WCA-2A	25	86	86	93	92	93
Southern WCA-2A	24	91	90	90	88	89
WCA-2B	23	92	84	86	81	80
Holey Land WMA	29	88	96	96	88	88
Rotenberger WMA	28	76	59	79	79	79
Northwest corner WCA-3A	22	91	76	92	94	95
Northwestern WCA-3A	20	91	81	87	88	88
Northeastern WCA-3A	21	85	74	92	83	85
Eastern WCA-3A	19	86	99	93	92	93
North Central WCA-3A	18	89	91	90	97	97
South Central WCA-3A	17	87	94	88	95	95
Southern WCA-3A	14	92	98	93	95	95
Western WCA-3B	15	92	96	92	97	98
Eastern WCA-3B	16	95	89	83	96	96
NE Shark River Slough	11	100	87	88	97	97
Central Shark River Slough	10	100	92	93	98	98
SW Shark River Slough	9	98	88	91	96	96
Rockland marl marsh	8	65	29	46	58	55

a. Data from the Inundation Duration Summary.

Table 37. Number of Weeks Water Levels Were Below The Low Water Depth Criterion in the Base Case and Alternative Simulations for the Everglades.[a]

Area Name	Indicator Region	Depth[b] (ft.)	NSM	1995 Base Case	2020 Base Case	2020 with Restudy	LEC-1
Northern WCA-1	27	< -1.0	27	6	11	3	1
Southern WCA-1	26	< -1.0	37	0	4	0	0
Northern WCA-2A	25	< -1.0	60	89	32	36	38
Southern WCA-2A	24	< -1.0	46	62	62	86	70
WCA-2B	23	< -1.0	22	104	71	99	103
Holey Land WMA	29	< -1.0	84	6	10	43	42
Rotenberger WMA	28	< -1.0	136	297	86	56	56
Northwest corner WCA-3A	22	< -1.0	36	181	36	22	19
Northwestern WCA-3A	20	< -1.0	36	119	66	48	44
Northeastern WCA-3A	21	< -1.0	106	194	45	79	65
Eastern WCA-3A	19	< -1.0	60	0	29	31	17
North Central WCA-3A	18	< -1.0	47	56	49	7	6
South Central WCA-3A	17	< -1.0	55	21	53	12	11
Southern WCA-3A	14	< -1.0	29	0	20	15	12
Western WCA-3B	15	< -1.0	5	1	9	6	4
Eastern WCA-3B	16	< -1.0	1	46	76	10	8
NE Shark River Slough	11	< -1.0	1	59	50	6	4
Central Shark River Slough	10	< -1.0	1	45	38	3	1
SW Shark River Slough	9	< -1.0	5	72	39	17	14
Rockland marl marsh	8	< -1.5	200	465	329	244	254

a. The desired condition is to go below the low depth as few times as possible.
b. The low water depth criterion is -1.0 feet below ground for peat-forming wetlands and -1.5 feet below ground for marl-forming marshes.

Table 38. Number of Weeks the High Water Depth Criterion was Exceeded in the Base Case and Alternative Simulations for the Everglades.[a]

Area Name	Indicator Region	Depth[b] (ft.)	NSM	1995 Base Case	2020 Base Case	2020 with Restudy	LEC-1
Northern WCA-1	27	>2.5	0	4	1	1	1
Southern WCA-1	26	>2.5	0	486	371	405	436
Northern WCA-2A	25	>2.5	0	0	0	12	17
Southern WCA-2A	24	>2.5	0	2	10	55	73
WCA-2B	23	>2.5	20	246	790	162	131
Holey Land WMA	29	>1.5	182	602	628	115	114
Rotenberger WMA	28	>1.5	76	0	0	0	0
Northwest corner WCA-3A	22	>2.5	0	0	0	0	0
Northwestern WCA-3A	20	>2.5	0	1	1	0	0
Northeastern WCA-3A	21	>2.0	3	15	13	32	38
Eastern WCA-3A	19	>2.5	0	877	235	322	373
North Central WCA-3A	18	>2.5	0	32	16	14	17
South Central WCA-3A	17	>2.5	0	65	40	15	18
Southern WCA-3A	14	>2.5	0	599	114	12	14
Western WCA-3B	15	>2.5	38	13	89	55	52
Eastern WCA-3B	16	>2.5	65	26	164	95	85
NE Shark River Slough	11	>2.5	144	0	0	53	46
Central Shark River Slough	10	>2.5	56	1	0	19	18
SW Shark River Slough	9	>2.5	0	0	0	0	0
Rockland marl marsh	8	>2.0	0	0	0	0	0

a. The desired condition is to exceed the high water depth as few times as possible.
b. Depth is the high water depth criterion.

Table 39. Duration of Average Annual Flooding in the Incremental Simulations for the Everglades.[a]

Area Name	Indicator Region	Percent of the Year					
		NSM[b]	1995 Revised Base Case	2005	2010	2015	LEC-1 Revised
Northern WCA-1	27	92	96	92	94	95	96
Southern WCA-1	26	89	99	96	97	98	99
Northern WCA-2A	25	86	86	92	89	92	93
Southern WCA-2A	24	91	90	86	89	91	91
WCA-2B	23	92	84	74	78	82	83
Holey Land WMA	29	88	96	96	87	88	88
Rotenberger WMA	28	76	59	74	79	79	79
Northwest corner WCA-3A	22	91	76	85	91	94	94
Northwestern WCA-3A	20	91	80	81	87	91	88
Northeastern WCA-3A	21	85	74	87	85	84	83
Eastern WCA-3A	19	86	98	99	91	91	93
North Central WCA-3A	18	89	91	89	94	98	97
South Central WCA-3A	17	87	94	93	90	93	95
Southern WCA-3A	14	92	98	98	92	91	95
Western WCA-3B	15	92	96	96	93	93	98
Eastern WCA-3B	16	95	89	88	90	90	96
NE Shark River Slough	11	100	87	87	86	91	97
Central Shark River Slough	10	100	92	90	92	94	98
SW Shark River Slough	9	98	88	89	91	92	96
Rockland marl marsh	8	65	29	58	51	53	55

a. Data from Inundation Duration Summary for the incremental simulation
b. NSM = Natural System Model version 4.5 Final

Table 40. Number of Weeks Water Levels Were Below the Low Water Depth Criterion in the Incremental Simulations for the Everglades.[a]

Area Name	Indicator Region	Depth[b] (ft)	NSM[c]	1995 Revised Base Case	2005	2010	2015	LEC-1 Revised
Northern WCA-1	27	< -1.0	27	6	13	6	4	1
Southern WCA-1	26	< -1.0	37	0	2	2	1	0
Northern WCA-2A	25	< -1.0	60	87	43	65	34	33
Southern WCA-2A	24	< -1.0	46	64	81	70	56	60
WCA-2B	23	< -1.0	22	110	184	142	105	89
Holey Land WMA	29	< -1.0	84	6	9	44	43	41
Rotenberger WMA	28	< -1.0	136	297	163	57	57	56
Northwest corner WCA-3A	22	< -1.0	36	185	92	35	22	14
Northwestern WCA-3A	20	< -1.0	36	123	121	63	28	43
Northeastern WCA-3A	21	< -1.0	106	195	97	104	85	91
Eastern WCA-3A	19	< -1.0	60	1	0	47	35	25
North Central WCA-3A	18	< -1.0	47	56	55	31	5	6
South Central WCA-3A	17	< -1.0	55	21	28	40	24	13
Southern WCA-3A	14	< -1.0	29	0	1	36	32	13
Western WCA-3B	15	< -1.0	5	1	2	27	29	5
Eastern WCA-3B	16	< -1.0	1	47	46	60	55	9
NE Shark River Slough	11	< -1.0	1	60	67	61	30	6
Central Shark River Slough	10	< -1.0	1	45	60	46	31	5
SW Shark River Slough	9	< -1.0	5	71	64	51	44	12
Rockland marl marsh	8	< -1.5	200	470	321	336	309	263

a. The desired condition is to go below the low water depth as few times as possible.
b. The low water depth criterion is -1.0 feet below ground for peat-forming wetlands and -1.5 feet below ground for marl-forming marshes.
c. NSM = Natural System Model version 4.5 Final

Table 41. Number of Weeks the High Water Depth Criterion was Exceeded in the Incremental Simulations for the Everglades.[a]

Area Name	Indicator Region	Depth[b] (ft)	NSM[c]	1995 Revised Base Case	2005	2010	2015	LEC-1 Revised
Northern WCA-1	27	>2.5	0	4	8	8	11	11
Southern WCA-1	26	>2.5	0	475	429	488	506	510
Northern WCA-2A	25	>2.5	0	0	0	10	12	11
Southern WCA-2A	24	>2.5	0	2	0	52	53	58
WCA-2B	23	>2.5	20	235	181	141	151	158
Holey Land WMA	29	>1.5	182	599	706	114	105	108
Rotenberger WMA	28	>1.5	76	0	0	0	0	0
Northwest corner WCA-3A	22	>2.5	0	0	0	0	0	0
Northwestern WCA-3A	20	>2.5	0	1	0	6	2	0
Northeastern WCA-3A	21	>2.0	3	15	6	26	25	30
Eastern WCA-3A	19	>2.5	0	860	315	137	144	351
North Central WCA-3A	18	>2.5	0	30	11	22	21	13
South Central WCA-3A	17	>2.5	0	64	23	27	28	14
Southern WCA-3A	14	>2.5	0	593	108	58	65	12
Western WCA-3B	15	>2.5	38	13	52	3	3	51
Eastern WCA-3B	16	>2.5	65	22	67	19	20	89
NE Shark River Slough	11	>2.5	144	0	49	20	20	52
Central Shark River Slough	10	>2.5	56	1	13	15	15	20
SW Shark River Slough	9	>2.5	0	0	0	0	0	0
Rockland marl marsh	8	>2.0	0	0	0	0	0	0

a. The desired condition is to exceed the high water depth as few times as possible.
b. Depth is the high water depth criterion.
c. NSM = Natural System Model version 4.5 Final

Loxahatchee National Wildlife Refuge (WCA-1)

Base Cases and Alternatives Results

1995 and 2020 Base Cases. The current U.S. Fish and Wildlife Service's (USFWS's) regulation schedule for the Arthur R. Marshall Loxahatchee National Wildlife Refuge (WCA-1) was in effect under the 1995 Base Case and was adopted as the performance target for the refuge at the request of refuge staff. Under these conditions this area met the proposed target and, therefore, was scored green for the 1995 Base Case (**Table 24**). Increased regional water supply demands under the 2020 Base Case showed a tendency toward slightly lower water levels and shorter hydroperiods as compared to the 1995 Base Case target. Overall, during the 2020 Base Case, the refuge had approximately a five percent shorter annual period of flooding (**Table 36**) and more weeks that water levels were below the low water criterion (**Table 37**). Because of these factors, this area was scored yellow for the 2020 Base Case (**Table 24**).

2020 with Restudy and LEC-1. Conditions in the Arthur R. Marshall Loxahatchee National Wildlife Refuge (WCA-1) met the proposed environmental performance targets in both the northern (Indicator Region 27) and southern (Indicator Region 26) sections and were scored green under the 2020 with Restudy and LEC-1 model simulations (**Table 24**).

Incremental Results

The current USFWS's regulation schedule for the Arthur R. Marshall Loxahatchee National Wildlife Refuge (WCA-1) was in effect under the 1995 Revised Base Case and was adopted as the performance target for the area. Under these conditions this area met the proposed target and, therefore, was scored green for the 1995 Revised Base Case (**Table 25**). Increased regional water supply demands under the 2005 simulation showed a tendency toward slightly lower water levels as compared to the 1995 Revised Base Case. Overall, the 2005 simulation had a shorter annual period of flooding (**Table 39**) and a small increase in the number of weeks that water levels were below the low water criterion (**Table 40**). Because of these factors, this area was scored green/yellow for the 2005 simulation (**Table 25**). However, conditions in the Arthur R. Marshall Loxahatchee National Wildlife Refuge (WCA-1) closely match the 1995 Revised Base Case for the 2010, 2015, and the LEC-1 Revised simulations (**Tables 39**, **40**, and **41**) and was scored green (**Table 25**).

Water Conservation Area 2A

Base Cases and Alternatives Results

1995 and 2020 Base Cases. Water levels were consistently higher and fluctuated over a wider range of water depths as compared to the NSM target in the 1995 and 2020 base cases for WCA-2A. In particular, northern WCA-2A (Indicator Region 25) exhibited wet and dry season water depth ranges in excess of NSM targets (**Tables 37** and **38**). These deeper water levels are presumed to be undesirable for the recovery and maintenance of the remaining tree islands. Under the base cases, the water levels in WCA-2A were below the low water depth criterion (number of times that water levels fell more than one foot below ground) more often than the NSM target (**Table 37**). These events are undesirable for the protection and accretion of peat soils. Although southern WCA-2A (Indicator Region 24) performed better, wet season surface water ponding generally elevated water levels above the NSM target range. WCA-2A was scored green/yellow for both simulations to account for differences in performance between northern and southern WCA-2A (**Table 24**).

2020 with Restudy and LEC-1. WCA-2A did not perform better in the 2020 with Restudy or LEC-1 alternatives, and was scored green/yellow (**Table 24**). Performance during the base case and alternative simulations was very similar. The main difference was that the high water criterion (number of weeks water depths exceeded 2.5 feet) was exceeded during more weeks under the 2020 with Restudy and LEC-1 simulations than during the 1995 and 2020 base cases (**Table 38**). It appears that water management in this area creates trade-offs between flooding and drying that are difficult to balance. Operational parameters or physical features can be further refined to bring the performance of this area closer to the NSM target.

Incremental Results

Overall, the northern and southern portions of WCA-2A contrasted in performance for the incremental simulations. Water levels and hydroperiods within northern WCA-2A (Indicator Region 25) came close to meeting NSM-defined targets (**Tables 39** and **41**). For this reason, northern WCA-2A was scored green for generally meeting the target. In contrast, under the 2010, 2015, and LEC-1 Revised simulations, southern WCA-2A (Indicator Region 24) exhibited water depths in excess of NSM-defined targets during wet years (**Tables 39** and **41**). These deep water conditions may be undesirable for the recovery and maintenance of remaining tree islands. For this reason, southern WCA-2A was scored yellow for these incremental simulations. Because of the large difference in performance between southern and northern WCA-2A, this area was given an overall scored of green/yellow for all of the incremental simulations (**Table 25**).

Water Conservation Area 2B

Base Cases and Alternatives Results

1995 and 2020 Base Cases. WCA-2B (Indicator Region 23) performed poorly in both the 1995 and 2020 base cases. Water levels were much higher and much more variable as compared to the NSM target (**Table 38**). Inundation patterns were of much longer duration (**Table 36**), with more frequent and more extreme high and low water periods (**Tables 37** and **38**). The high water criterion (number of weeks that surface water depth was greater than 2.5 feet) was exceeded 50 percent of the time in the 2020 Base Case. These sustained inundation depths would be detrimental to tree island and sawgrass communities within this WCA. Annual ranges of depth between wet and dry seasons were larger than the target. Many of the problems in this area are due to its relatively small size; its location above the Biscayne aquifer, which results in large seepage losses; its unusual shape that promotes ponding in its southern end; and its position in the landscape. Because of the magnitude of difference between the NSM target and the 1995 Base Case, this area was scored red (**Table 24**).

2020 with Restudy and LEC-1. Although a number of different management strategies (e.g., rain-driven system, regulation schedule) have been tried within the Restudy and LEC regional water supply planning efforts, few have been successful in meeting NSM targets for this area. The 2020 with Restudy and LEC-1 alternatives also had problems meeting both high water and low water criteria (**Tables 37** and **38**). However, the LEC-1 simulation performed better than the 2020 with Restudy. Although these events were not as severe as those in the base cases, sufficient deviations from the NSM target occurred to warrant a red score for this area (**Table 24**).

Incremental Results

WCA-2B (Indicator Region 23) performed poorly in both the 1995 Revised Base Case and throughout the incremental simulations. In the 1995 Revised Base Case, water levels were much higher and much more variable as compared to the NSM targets (**Tables 40** and **41**). Inundation patterns were of much longer duration (**Table 39**), with more frequent and more extreme high water and low water periods (**Tables 40** and **41**). The high water criterion was often exceeded. Sustained inundation depths near or greater than 2.5 feet would be detrimental to tree island and sawgrass communities within this WCA. Annual ranges of water depths between wet and dry seasons were larger than the target. Although problems with high water improved somewhat through time, this came with a trade-off of significant increases in the occurrence of drying events. For all incremental simulations, WCA-2B was scored red (**Table 25**). Alternate D13R of the Restudy recognized this problem and arrived at the same conclusions (USACE and SFWMD, 1999). Many of the problems in this area are due to its relatively small size; its location above the Biscayne aquifer, which results in large seepage losses; its unusual shape that promotes ponding in its southern end; and its position in the landscape.

Holey Land and Rotenberger Wildlife Management Areas

Base Cases and Alternatives Results

1995 and 2020 Base Cases. For the 1995 and 2020 base cases, the Holey Land WMA (Indicator Region 29) had higher water levels than the NSM target (**Table 38**). The high water depth criterion was exceeded during more than 600 weeks, which was more than three times the target (**Table 38**). This was due to the fact that the FWC's regulation schedule was in effect. Water levels exceeded the high water criterion for approximately 35 percent of the year and low water periods were infrequent. For this reason, the Holey Land WMA was scored yellow for the 1995 and 2020 base cases. In contrast, in the 1995 Base Case, the Rotenberger WMA (Indicator Region 28) had a much shorter average annual inundation period than the target (**Table 36**). In the 1995 Base Case, this area had more than double the number of weeks that water levels were below the low water depth criterion (one foot below the soil surface) (**Table 37**), and for this reason, the Rotenberger WMA was scored red for the 1995 Base Case (**Table 24**). In the 2020 Base Case, conditions improved greatly in this WMA due to the operation of upstream STAs and the Rotenberger WMA was scored green for this simulation (**Table 24**).

2020 with Restudy and LEC-1. Conditions in the Holey Land and Rotenberger WMAs were much improved in both the 2020 with Restudy and LEC-1 alternatives. Water levels were maintained near that of the NSM targets (**Table 37** and **38**) and, for this reason, both WMAs were scored green for these alternatives (**Table 24**).

Incremental Results

Generally, the Holey Land and Rotenberger WMAs showed incremental improvements over the base case conditions and NSM-defined targets were met during the 2010 simulation (**Tables 39**, **40**, and **41**). For the 1995 Revised Base Case and 2005 simulations, the Holey Land WMA (Indicator Region 29) had higher water levels than the NSM target (**Table 41**). This was due to the fact that the FWC's regulation schedule was in effect. The number of weeks that the high water depth criterion was exceeded was more than three times the target for these two simulations (**Table 41**). Water levels exceeded the high water criterion for more than 30 percent of the year and low water periods were infrequent (**Table 40**). For this reason, the Holey Land WMA was scored red for the 1995 Revised Base Case and the 2005 simulations. In contrast, the Rotenberger WMA (Indicator Region 28) had a much shorter average annual inundation period in the 1995 Revised Base Case than the target (**Table 39**). This area had more than double the number of weeks that water levels were below the low water depth criterion (one foot below the soil surface) compared to the NSM target (**Table 40**). As a result, the Rotenberger WMA was scored red for the 1995 Revised Base Case. During the 2005 simulation, conditions improved greatly in this WMA due to the operation of upstream STAs and the area was scored yellow. Performance was near that of the NSM targets in both the Holey Land and Rotenberger WMAs during the 2010, 2015, and LEC-1 Revised simulations and the WMAs were scored green for these simulations (**Table 25**).

Northern Water Conservation Area 3A

Base Cases and Alternatives Results

1995 and 2020 Base Cases. Northeastern WCA-3A (Indicator Region 21) performed poorly in the 1995 Base Case. In general, this area had a problem with both high and low water extremes (**Tables 37** and **38**). This area had 11 percent less average annual duration of flooding (**Table 36**), indicating that more severe drying events occurred. Performance improved somewhat in the 2020 Base Case, prompting a change from a red score in the 1995 Base Case to yellow in the 2020 Base Case (**Table 24**).

In the 1995 Base Case, northwestern WCA-3A (Indicator Regions 20 and 22) suffered from chronic low water conditions and overdrained conditions in most years (**Table 37**). As compared to the NSM target, the average period of annual flooding was more than 10 percent shorter (**Table 36**), resulting in extended periods of more severe drying increasing the frequency of muck fires, which impact tree islands and wildlife. Because of these problems, northwestern WCA-3A was scored red in the 1995 Base Case (**Table 24**). Under the 2020 Base Case, conditions improved significantly with the operation of the STAs to the north of WCA-3A (**Tables 36**, **37**, and **38**). This increased hydroperiod gave this area more NSM-like hydrology. Therefore, northwestern WCA-3A was scored green for the 2020 Base Case (**Table 24**).

2020 with Restudy and LEC-1. In both the 2020 with Restudy and LEC-1 alternatives, northern WCA-3A performed well and showed much improvement over the 1995 and 2020 base cases (**Tables 36**, **37**, and **38**). The hydropatterns were NSM-like, aided by the operation of the EAA Storage Reservoirs, the completed STAs to the north, and other Restudy components. This area was scored green in both alternatives (**Table 24**).

Incremental Results

Generally, northern WCA-3A showed incremental improvements over the base case conditions and NSM-defined targets were met by 2010. Northern WCA-3A (Indicator Regions 20, 21, and 22) performed poorly in the 1995 Revised Base Case. In general, this area had a problem with drying and water levels often fell below the low water criterion (depth more than one foot below the soil surface) (**Table 40**). Performance improved somewhat in 2005, prompting a change from a red score in the 1995 Revised Base Case to yellow/green (**Table 25**). By 2010, NSM targets were close to being met in all northern WCA-3 indicator regions, and this trend continued through 2020. Much of this improvement can be attributed to the construction and operation of STAs and completion of the EAA Storage Reservoirs along the northern boundary of WCA-3A.

Eastern Water Conservation Area 3A

Base Cases and Alternatives Results

1995 and 2020 Base Cases. Eastern WCA-3A (Indicator Region 19) performed poorly in the 1995 Base Case. Water levels were much higher and much more variable than in the NSM target (**Table 38**). Inundation patterns were of much longer duration (**Table 36**), with more frequent and extreme high water periods (**Table 38**). The high water depth criterion was exceeded approximately 55 percent of the time and this area was scored red (**Table 24**). Performance improved some in the 2020 Base Case. Prolonged high water events were reduced (**Table 38**), although annual flooding was still much longer than the NSM targets (**Table 36**). In the 2020 Base Case, eastern WCA-3A was scored yellow (**Table 24**), indicating marginal ability to meet LEC planning targets.

2020 with Restudy and LEC-1. Eastern WCA-3A was also scored yellow in the 2020 with Restudy and LEC-1 alternatives (**Table 24**). Problems similar to those seen the 2020 Base Case, such as longer annual flooding (**Table 36**) and more weeks that the high water criterion has been exceeded (**Table 38**) than the NSM target continue to exist.

Incremental Results

Eastern WCA-3A (Indicator Region 19) performed poorly in the 1995 Revised Base Case. Water levels were much higher and much more variable than the NSM targets (**Table 41**). Inundation occurred for much longer periods (**Table 39**), with more frequent and extreme high water conditions (**Table 41**) and, therefore, this area was scored red (**Table 25**). Performance improved in 2005. Prolonged high water events were reduced, although annual flooding still exceeded the NSM target (**Table 39**). No further improvements were seen through 2020 and eastern WCA-3A was scored yellow for the remaining incremental simulations (2005, 2010, 2015, and LEC-1 Revised) (**Table 25**), indicating marginal or uncertain ability to meet LEC planning targets.

Central Water Conservation Area 3A

Base Cases and Alternatives Results

1995 and 2020 Base Cases. Central WCA-3A (Indicator Regions 17 and 18) generally had increased numbers of extreme high water events (**Table 38**) and longer duration of flooding (**Table 36**) than the NSM targets for this area. Indicator region 18 recorded both extreme high and extreme low water levels (**Tables 37** and **38**) and was scored red for the 1995 and 2020 base cases (**Table 24**). Indicator Region 17, exhibited a number of extreme high water events (**Table 38**) that could potentially impact existing tree island vegetation in central WCA-3A. Therefore, this area was scored yellow under the 1995 and 2020 bases cases (**Table 24**).

2020 with Restudy and LEC-1. Central WCA-3A showed a number of improvements in both hydropattern (more NSM-like) and reduction of extreme high water events for the 2020 with Restudy and LEC-1 alternatives relative to the base cases (**Tables 36** and **38**). Indicator Region 17, located in south central WCA-3A, performed well with respect to meeting NSM targets and was scored green. In contrast, Indicator Region 18 exhibited prolonged hydroperiods in excess of the NSM target (**Table 36**), but did show a reduction in the number of both extreme high and low water events (**Tables 37** and **38**) as compared to the bases cases. Prolonged hydroperiods exhibited during the 2020 with Restudy and LEC-1 simulation appear to be the result of the relocation of Pump Station S-140 to the south of Alligator Alley, which moves a good deal more water across Indicator Region 18, and prevents the area from drying out. For these reasons Indicator Region 18 was scored yellow.

Incremental Results

In the 1995 Revised Base Case, central WCA-3A (Indicator Regions 17 and 18) generally experienced more extreme high water events (**Table 41**) and had longer duration of flooding as compared to the NSM target (**Table 39**). Under the 1995 Revised Base Case, the increased numbers of extreme high water events could potentially cause damage to existing tree island communities. For this reason this area was scored red for Indicator Region 18 and yellow for Indicator Region 17 (**Table 25**).

By 2005, Indicator Region 17 showed an improved ability to meet NSM hydropattern targets (**Table 39**), and a reduced number of extreme high water events (**Table 38**). In contrast, Indicator Region 18 remained problematic with prolonged hydroperiods in excess of the NSM target (**Table 39**). Again these problems appeared to be associated with the relocation of Pump Station S-140. For these reasons, Indicator Region 17 was scored green and Indicator Region 18 was scored yellow for the 2005, 2010, 2015, and LEC-1 Revised simulations.

Southern Water Conservation Area 3A

Base Cases and Alternatives Results

1995 and 2020 Base Cases. In the base cases, water in southern WCA-3A (Indicator Region 14) tended to pond and caused excessive flooding (**Tables 36** and **38**). Here, the high water depth criterion was exceeded more than 35 percent of the time during the 31-year simulation period. This condition is unfavorable for the protection of tree island or sawgrass communities. Because of the extreme nature of these problems, this area was scored red in both base cases (**Table 24**).

2020 with Restudy and LEC-1. In both the 2020 with Restudy and LEC-1 alternatives, southern WCA-3A performs well. The hydropatterns were NSM-like and were greatly improved over the 1995 and 2020 base cases (**Tables 36**, **37**, and **38**). This area was scored green for both alternatives (**Table 24**).

Incremental Results

Southern WCA-3A showed gradual improvement from the 1995 Revised Base Case simulation through the LEC-1 Revised simulation. In the 1995 Revised Base Case, water in southern WCA-3A (Indicator Region 14) tended to pond (**Table 39**) and caused excessive flooding (**Table 41**). This condition is unfavorable for the protection of tree island or sawgrass communities. Because of these extreme high water problems, this area was scored red for the 1995 Revised Base Case (**Table 25**). Improvement of performance was seen in the 2005, 2010, and 2015 simulations, where the severity of high water problems was moderated (**Table 41**). However, the NSM-defined targets were not met during these time frames, so a score of yellow was assigned (**Table 25**). Southern WCA-3A performed well in the LEC-1 Revised simulation. Hydropatterns were similar to the NSM target (**Tables 39**, **40**, and **41**) and this area was scored green for the LEC-1 Revised simulation (**Table 25**).

Water Conservation Area 3B

Base Cases and Alternatives Results

1995 and 2020 Base Cases. Eastern WCA-3B (Indicator Region 16) was overall drier on average as compared to the NSM targets for both base cases (**Table 36**). Under the 2020 Base Case, eastern WCA-3B experienced a larger number of weeks that water levels fell below the low water criterion and a larger number of weeks that the high water criterion were exceeded compared to NSM targets (**Tables 37** and **38**). In contrast, western WCA-3B (Indicator Region 15) experienced average annual flooding events (hydroperiod) similar to NSM targets for both base cases (**Table 36**), however, this area also experienced a larger number of weeks that water levels fell below the low water criterion and a larger number of weeks that the high water criterion were exceeded compared to NSM targets (**Tables 37** and **38**). For these reasons WCA-3B was scored yellow (**Table 24**) indicating that this area of the Everglades has marginal or uncertain ability to achieve recovery or long-term sustainability. Hydrologic improvements are needed to meet LEC planning targets.

2020 with Restudy and LEC-1. Although the duration of average annual flooding (hydroperiod) for both the LEC 2020 with Restudy and LEC-1 alternatives were close to NSM values, too many high water events that impact the area occurred (**Table 38**). For this reason WCA-3B continued to be scored yellow for both of the alternatives (**Table 24**).

Incremental Results

For the 1955 Revised Base Case, western WCA-3B (Indicator Region 15) tended to be flooded longer and had a fewer number of extreme low water events as compared to the NSM target (**Tables 39** and **40**). Conversely, eastern WCA-3B (Indicator Region 16) was overall drier than the target leading to a larger number of weeks that water levels fell below the low water depth criterion (**Table 40**). These conditions did not improve significantly until the LEC-1 Revised simulation, when additional operational and structural features were in place to resolve some of these problems. As a result, both eastern and western WCA-3B were scored intermediate between yellow and green (yellow/green) for the LEC-1 Revised simulation indicating that hydrologic restoration of the area appears close to the NSM target. However, there is still room for improvement in these areas (**Table 25**).

Shark River Slough

Base Cases and Alternatives Results

1995 and 2020 Base Cases. Under both base cases, water levels in northeastern Shark River Slough (Indicator Region 11) were below the low water depth criterion more often (**Table 37**) and the duration of annual flooding (hydroperiod) in the area was significantly less (**Table 36**) when compared to the NSM targets. Similar problems with low water levels and increased number of dry downs occurred in central and southwestern Shark River Slough (Indicator Regions 9 and 10) under the base cases (**Tables 36** and **37**). This excessive drying is unfavorable for development or preservation of peat soils and protection of wetland plant and animal communities. For this reason, this area was scored red for both the 1995 and 2020 base cases (**Table 24**).

2020 with Restudy and LEC-1. The performance of the 2020 with Restudy and LEC-1 alternatives for Shark River Slough was much improved compared to the base cases (**Tables 36**, **37**, and **38**). Significantly more water was delivered to the system, which increased the duration of annual flooding and reduced the number of times this area dried out as compared to the base cases. Improvements both in the quantity and timing of water delivered to Shark River Slough occurred primarily because a number of Restudy projects came on-line by 2020. These components included the completion of 50 percent of the Lake Belt Storage Area components, decompartmentalization of WCA-3, and enhanced flows under Tamiami Trail. Because performance was significantly improved over the base cases, but still did not quite meet the NSM target, this area was scored as intermediate between green and yellow (green/yellow) (**Table 24**).

Incremental Results

In the 1995 Revised Base Case and 2005 simulations, water levels throughout Shark River Slough (Indicator Regions 9, 10, and 11) were below the low water depth criterion more often (**Table 40**) and the duration of annual flooding in the area was significantly less (**Table 39**) compared to the NSM targets. This excessive drying is unfavorable for development or preservation of peat soils and protection of wetland plant and animal communities. Furthermore, Shark River Slough had a tendency toward early dry season recession of the surface water during these simulations. This can be problematic for wildlife species that rely on timing of the dry season dry downs for foraging or reproduction cycles. For this reason, Shark River Slough was scored red for both the 1995 Revised Base Case and 2005 simulations (**Table 25**).

Modeling results showed a gradual improvement over time to provide increased flows to Everglades National Park. Beginning with the 2005 simulation, a significant improvement in both the distribution and volume of water delivered to northeastern and northwestern Shark River Slough occurred (**Table 42**).In the 2010 simulation, significant improvements in meeting NSM hydroperiod targets were recorded within northeastern and central Shark River Slough (**Tables 39**, **40**, and **41**). One hundred percent of the slough matched the NSM hydroperiod target in the LEC-1 Revised simulation (**Table 43**). However, because performance was still short of the target, this area was scored intermediate between green and yellow (green/yellow) for the LEC-1 Revised simulation (**Table 25**).

Table 42. Total Average Annual Flows Discharged into Northern Everglades National Park, East and West of L-67A (1000 ac-ft).

Area	Average Annual Flow (ac-ft x 1,000)				
	1995 Revised Base Case	2005	2010	2015	LEC-1 Revised
NW Shark River Slough	461	568	397	434	579
NE Shark River Slough	88	402	524	596	685
Total	549	970	921	1,030	1,264

Table 43. Mean NSM Hydroperiod Matches with Respect to NSM.[a]

Area	1995 Revised Base Case	2005	2010	2015	LEC-1 Revised
Everglades[b]	58%	64%	74%	77%	78%
WCAs[c]	64%	69%	80%	79%	75%
Everglades National Park	54%	60%	66%	75%	87%
Shark River Slough[d]	53%	44%	71%	95%	100%
Rockland Marl Marsh[d]	49%	70%	65%	67%	75%

a. Match corresponds to a match with the NSM target +/- 30 hydroperiod days
b. Includes WCAs, Holey Land and Rotenberger WMAs, and Everglades National Park
c. Includes WCA-1, 2A, 2B, 3A, and 3B
d. Within Everglades National Park

Rockland Marl Marsh

Base Cases and Alternatives Results

1995 and 2020 Base Cases. The Rockland marl marsh area of Everglades National Park (Indicator Region 8) performed poorly in both the 1995 and 2020 base cases. This area had problems with extremely low water levels. Water levels were often below the low water depth criterion (**Table 37**). This excessive drying is unfavorable for development or preservation of marl soils. This area was scored red for both base cases (**Table 24**).

2020 with Restudy and LEC-1. Performance of the Rockland Marl Marsh improved significantly in the 2020 with Restudy and LEC-1 alternatives. More water was delivered to the system and the hydroperiod was much closer to the NSM target than for the base cases (**Tables 36** and **37**). Because performance was still short of the target, this area was scored yellow (**Table 24**).

Incremental Results

The Rockland marl marsh area of Everglades National Park (Indicator Region 8) performed poorly in the 1995 Revised Base Case. Water levels in this area were below the low water depth criterion more often than the NSM target (**Table 40**). Excessive drying is unfavorable for development or preservation of marl soils, and, therefore, a score of red was assigned to the 1995 Revised Base Case (**Table 25**).

The incremental simulations showed improved performance through time. By 2005, more water was delivered to the system and the hydroperiod was much closer to the NSM target than for the base cases (**Tables 39** and **40**). Performance continued to improve from 2005 through 2020, as shown by sequential decreases in the number of weeks that water levels were below the low water depth criterion (**Table 40**) and closer hydroperiod matches to the NSM-defined target (**Table 43)**. Although significant hydroperiod improvements were noted, this area was scored yellow to indicate for the LEC-1 Revised that performance was still short of the NSM target in 2020 (**Table 25**). Alternative D13R from the Restudy indicated similar problems with lowered water levels for the Rockland marl marsh (USACE and SFWMD, 1999).

Minimum Flows and Levels

Model results for MFLs were evaluated at the level of key gage stations. The locations of the key gages are shown in **Figure 28**. **Table 44** provides a summary of the proposed MFL criteria for the Everglades. These MFL criteria were proposed in the *Minimum Flows and Levels for Lake Okeechobee, the Everglades, and the Biscayne Aquifer* (SFWMD, 2000e).

Base Cases and Alternatives Results

1995 Base Case. Under the 1995 Base Case, proposed minimum water level criteria were not met for 12 out of 19 indicator regions located within the northern Everglades and Everglades National Park (**Table 45**). This was due largely to impoundment of these marshes and the construction of major canals throughout the northern Everglades as part of the C&SF Project. During dry periods, these canals lower ground water levels and over drain these wetlands, causing extensive peat fires, soil subsidence, changes in Everglades vegetation communities, and impacts to wildlife species. MFLs were not met in the Rotenberger WMA, northern WCA-3A, and WCA-3B. In Everglades National Park, MFLs were not met within Shark River Slough, the Rockland marl marsh, and marl wetlands located east and west of Shark River Slough. Areas that did meet the proposed criteria included the Arthur R. Marshall Loxahatchee National Wildlife Refuge (WCA-1); WCA-2A; WCA-2B; Holey Land WMA; central and southern WCA-3A; and Taylor Slough (**Table 45**).

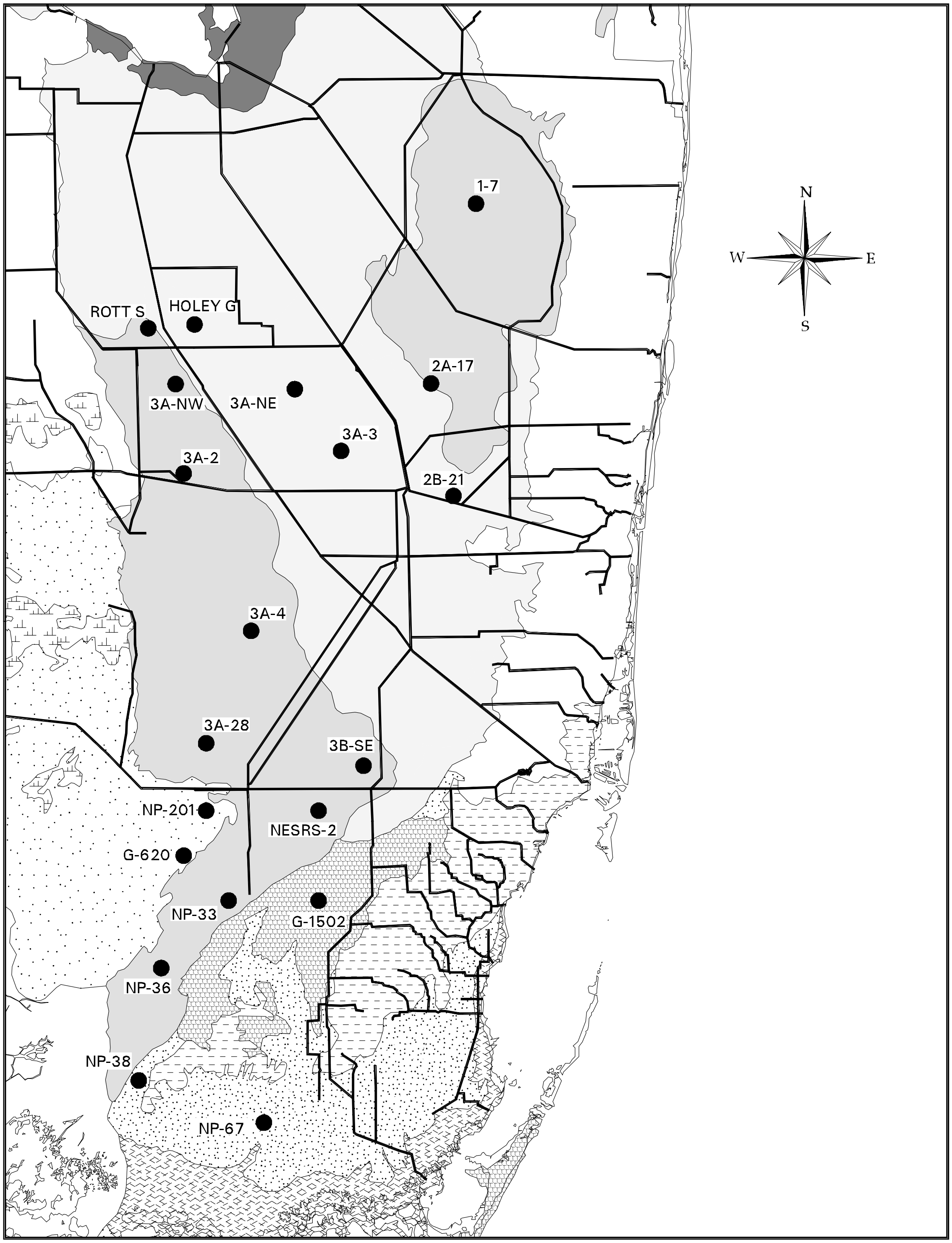

Figure 28. Location of Key Gages Used for Minimum Flows and Levels Simulations.

Table 44. Minimum Water Level, Duration, and Return Frequency Performance Measures for Selected Water Management Gages Located within the Everglades (SFWMD, 2000e).

Area	Key Gage	Indicator Region[a]	Soil Type	Minimum Depth (ft) and Duration (days)	Return Frequency (years)[b]
Loxahatchee National Wildlife Refuge (WCA-1)	1-7	27	Peat	-1.0 ft > 30 days	1-in-4
WCA-2A	2A-17	24	Peat	-1.0 ft > 30 days	1-in-4
WCA-2B	2B-21	23	Peat	-1.0 ft > 30 days	1-in-3[c]
Holey Land WMA	HoleyG	29	Peat	-1.0 ft > 30 days	1-in-3
Rotenberger WMA	Rotts	28	Peat	-1.0 ft > 30 days	1-in-2
Northwest corner of WCA-3A	3A-NW	22	Peat	-1.0 ft > 30 days	1-in-4
Northwestern WCA-3A	3A-2	20	Peat	-1.0 ft > 30 days	1-in-4
Northeastern corner of WCA-3A	3A-3	68	Peat	-1.0 ft > 30 days	1-in-3
Northeastern WCA-3A	3A-NE	21	Peat	-1.0 ft > 30 days	1-in-2
Central WCA-3A	3A-4	17	Peat	-1.0 ft > 30 days	1-in-4
Southern WCA-3A	3A-28	14	Peat	-1.0 ft > 30 days	1-in-4
WCA-3B	3B-SE	16	Peat	-1.0 ft > 30 days	1-in-7
Northeastern Shark River Slough	NESRS-2	11	Peat	-1.0 ft > 30 days	1-in-10
Central Shark River Slough	NP-33	10	Peat	-1.0 ft > 30 days	1-in-10
Southwestern Shark River Slough	NP 36	9	Peat	-1.0 ft > 30 days	1-in-7
Marl wetlands east of Shark River Slough	NP-38	70	Marl	-1.5 ft > 90 days	1-in-3[d]
Marl wetlands west of Shark River Slough	NP-201 G-620	12	Marl	-1.5 ft > 90 days	1-in-5
Rockland Marl Marsh	G-1502	8	Marl	-1.5 ft > 90 days	1-in-2[d]
Taylor Slough	NP-67	1	Marl	-1.5 ft > 90 days	1-in-2[d]

a. See **Figure 27** for the location of each indicator region

b. Return frequencies for peat based wetlands located within the WCAs were based largely on output of the Natural System Model, version 4.5 Final.

c. Expert opinion of District staff and results from the NSM concur that a 1-in-6 return frequency is needed to protect peat soils of this region from significant harm. District staff recognizes that this value had to be modified to account for consideration of changes and structural alterations that have occurred to the hydrology of WCA-2B. Model results of the Restudy and LEC water supply planning process suggest full restoration of WCA-2B may not be possible. A policy decision was made to present a MFL return frequency of 1-in-3 in this table to reflect conditions that can be practically achieved.

d. These return frequencies reflect the expert opinion of District staff based on agreed upon management targets developed for the Restudy and LEC Plan and output of the NSM. It is the expert opinion of Everglades National Park staff that NSM does not properly simulate hydrologic conditions within the Rockland marl marsh and Taylor Slough, and the proposed return frequencies listed above may not necessarily protect these marl-forming wetlands from significant harm. They propose that a frequency of 1-in-5 may be necessary to prevent significant harm from occurring to these unique areas of Everglades National Park.

2020 Base Case. The ability of the regional system to meet MFLs did not improve under the 2020 Base Case. As in the 1995 Base Case, 12 out of 19 indicator regions exceeded the proposed criteria (**Table 45**). However, northeastern WCA-3A showed hydroperiod improvements associated with completion of STA-3 and STA-4 and the reestablishment of sheetflow to northeastern WCA-3A.

2020 with Restudy and LEC-1. Implementation of the 2020 with Restudy and LEC-1 alternatives significantly improved the system's ability to meet proposed MFL criteria. Under the 2020 with Restudy simulation, 17 of 19 sites met the proposed criteria (**Table 45**). MFL performance was slightly improved under LEC-1, with 18 out of 19 indicator regions meeting the proposed criteria. Areas that showed the most improvement were WCA-3A, WCA-3B, and Shark River Slough. Areas that still need improvement included WCA-2A, the marl wetlands east of Shark River Slough, and the Rockland marl marsh. (**Table 45**).

Table 45. Minimum Flows and Levels Results of the Base Case and Alternative Simulations for the Everglades.[a]

Geographic Location				Return Frequency (Years)				
Area	**Key Gage**	**IR[b]**	**Soil[c]**	**Target**	**1995 Base Case**	**2020 Base Case**	**2020 With Restudy**	**LEC-1**
Loxahatchee National Wildlife Refuge (WCA-1)	1-7	27	peat	1-in-4	1-in-15	1-in-4	1-in-10	1-in-15
WCA-2A	2A-17	24	peat	1-in-4	1-in-4	1-in-4	1-in-3	1-in-3
WCA-2B	2B-21	23	peat	1-in-3	1-in-3	1-in-4	1-in-3	1-in-3
Holey Land WMA	HoleyG	29	peat	1-in-3	1-in-5	1-in-6	1-in-3	1-in-3
Rotenberger WMA	Rotts	28	peat	1-in-2	1-in-1	1-in-1	1-in-2	1-in-2
Northwest corner of WCA-3A	3A-NW	22	peat	1-in-4	1-in-1.5	1-in-3	1-in-4	1-in-6
Northwestern WCA-3A	3A-2	20	peat	1-in-4	1-in-2	1-in-3	1-in-4	1-in-4
Northeastern corner of WCA-3A	3A-3	68	peat	1-in-3	1-in-5	1-in-3	1-in-3	1-in-3
Northeastern WCA-3A	3A-NE	21	peat	1-in-2	1-in-1.6	1-in-4	1-in-2	1-in-2
Central WCA-3A	3A-4	17	peat	1-in-4	1-in-5	1-in-3	1-in-8	1-in-8
Southern WCA-3A	3A-28	14	peat	1-in-4	PF	1-in-4	1-in-6	1-in-8
WCA-3B	3B-SE	16	peat	1-in-7	1-in-3	1-in-2	1-in-10	1-in-10
Northeastern Shark River Slough	NESRS-2	11	peat	1-in-10	1-in-3	1-in-3	1-in-15	1-in-15
Central Shark River Slough	NP-33	10	peat	1-in-10	1-in-3	1-in-4	1-in-15	1-in-15
Southwestern Shark River Slough	NP-36	9	peat	1-in-7	1-in-3	1-in-4	1-in-8	1-in-8
Marl wetlands east of Shark River Slough	NP-38	70	marl	1-in-3	1-in-1.2	1-in-2	1-in-2	1-in-3
Marl wetlands west of Shark River Slough	NP-201/ G-620	12	marl	1-in-5	1-in-3	1-in-3	1-in-6	1-in-6
Rockland Marl Marsh	G-1502	8	marl	1-in-2	1-in- 1	1-in-1.3	1-in-1.3	1-in-1.5
Taylor Slough	NP-67	1	marl	1-in-2	1-in-2	1-in-2	1-in-2	1-in-2
Total Violations (number of sites which did not meet criteria)					12/19	12/19	3/19	2/19

a. [white box] = exceeded proposed MFL criteria; [shaded box] = met proposed MFL criteria
b. IR = Indicator Region
c. MFL Criteria for peat-forming wetlands are -1.0 feet below ground for more than 30 days; MFL criteria for marl-forming wetlands are -1.5 feet below ground for more than 90 days

Incremental Results

1995 Revised Base Case. Model simulations showed that under the 1995 Revised Base Case, proposed minimum water level criteria were not met for 11 out of 19 indicator regions (**Table 46**). MFLs were not met in the Rotenberger WMA, most of northern WCA-3A, WCA-3B, Shark River Slough, marl wetlands located east and west of Shark River Slough, and the Rockland marl marsh. Areas that met the proposed criteria were the Arthur R. Marshall Loxahatchee National Wildlife Refuge (WCA-1), WCA-2A, WCA-2B, the Holey Land WMA, the northeastern corner of WCA-3A (Indicator Region 68), central and southern WCA-3A, and Taylor Slough.

2010, 2015, and LEC-1 Revised. Conditions did not begin to improve in the northern Everglades until the 2010 simulation, and improvements continued incrementally through 2020 (LEC-1 Revised) when almost all areas met MFL criteria. In Everglades National Park, performance did not improve until the LEC-1 Revised simulation. This was primarily due to Lake Belt Project components not being implemented until 2020. Proposed Everglades MFL criteria were met at 17 out of the 19 indicator regions during the LEC-1 Revised simulation (**Table 46**). The two areas where MFLs were not met were WCA-2B and the Rockland marl marsh located in Everglades National Park.

2005 and 2005 SSM Scenario. Review of MFL performance for the Everglades showed no major differences between the 2005 incremental simulation and the 2005 SSM Scenario results (**Table 46**). After review of stage hydrographs, stage duration curves, inundation summary tables, and high and low water criteria (**Appendix H**) it was concluded that differences, if any, between the 2005 incremental simulation and the 2005 SSM Scenario were insignificant. All performance measures, including meeting MFLs, for the Everglades showed virtually identical behavior under both simulations.

Biscayne Bay

Performance Measures Applied

For purposes of this study, the performance measure for Biscayne Bay was that future flows delivered to the estuary should not be less than those currently discharged to the bay under the 1995 Base Case. Mean annual wet and dry season flows were based on SFWMM output for the primary water management structures which discharge into the northern, central, and southern portions of Biscayne Bay. These structures included the following:

- Northern Biscayne Bay: Snake Creek (S-29), G-58, S-28, and S-27
- Central Biscayne Bay: Miami River (S-25, S-25B, and S-26), G-97, S-22, and S-123
- Southern Biscayne Bay: S-21, S-21A, S-20F, and S-206

Table 46. Minimum Flows and Levels Results of the Incremental Simulations.[a]

Geographic Location				Return Frequency (Years)						
Area	Key Gage	IR[b]	Soil[c]	Target	1995 Revised Base Case	2005	2005 SSM Scenario	2010	2015	LEC-1 Revised
Loxahatchee National Wildlife Refuge (WCA-1)	1-7	27	peat	1-in-4	1-in-15	1-in-4	1-in-6	1-in-10	1-in-15	1-in-15
WCA-2A	2A-17	24	peat	1-in-4	1-in-4	1-in-4	1-in-2	1-in-3	1-in-3	1-in-4
WCA-2B	2B-21	23	peat	1-in-3	1-in-3	1-in-4	1-in-2	1-in-3	1-in-3	1-in-2
Holey Land WMA	HoleyG	29	peat	1-in-3	1-in-5	1-in-6	1-in-8	1-in-3	1-in-3	1-in-3
Rotenberger WMA	Rotts	28	peat	1-in-2	1-in-1	1-in-1	1-in-1	1-in-2	1-in-2	1-in-2
Northwest corner of WCA-3A	3A-NW	22	peat	1-in-4	1-in-1.5	1-in-3	1-in-2	1-in-4	1-in-6	1-in-8
Northwestern WCA-3A	3A-2	20	peat	1-in-4	1-in-2	1-in-3	1-in-2	1-in-4	1-in-4	1-in-3
Northeastern corner of WCA-3A	3A-3	68	peat	1-in-3	1-in-5	1-in-3	1-in-4	1-in-3	1-in-3	1-in-4
Northeastern WCA-3A	3A-NE	21	peat	1-in-2	1-in-1.6	1-in-4	1-in-3	1-in-2	1-in-2	1-in-2
Central WCA-3A	3A-4	17	peat	1-in-4	1-in-5	1-in-3	1-in-4	1-in-8	1-in-8	1-in-8
Southern WCA-3A	3A-28	14	peat	1-in-4	PF[d]	1-in-4	1-in-31	1-in-6	1-in-8	1-in-8
WCA-3B	3B-SE	16	peat	1-in-7	1-in-3	1-in-2	1-in-3	1-in-10	1-in-10	1-in-30
Northeastern Shark River Slough	NESRS-2	11	peat	1-in-10	1-in-3	1-in-3	1-in-3	1-in-15	1-in-15	1-in-30
Central Shark River Slough	NP-33	10	peat	1-in-10	1-in-3	1-in-4	1-in-3	1-in-15	1-in-15	PF
Southwestern Shark River Slough	NP-36	9	peat	1-in-7	1-in-3	1-in-4	1-in-3	1-in-8	1-in-8	1-in-8
Marl wetlands east of Shark River Slough	NP-38	70	marl	1-in-3	1-in-1	1-in-2	1-in-2	1-in-2	1-in-3	1-in-3
Marl wetlands west of Shark River Slough	NP-201	12	marl	1-in-5	1-in-3	1-in-3	1-in-3	1-in-6	1-in-6	1-in-6
Rockland Marl Marsh	G-1502	8	marl	1-in-2	1-in-1	1-in-1	1-in-1.5	1-in-1	1-in-1.5	1-in-1.7
Taylor Slough	NP-67	1	marl	1-in-2	1-in-2	1-in-2	1-in-2	1-in-2	1-in-2	1-in-2
Total Violations (number of sites which did not meet criteria)					11/19	11/19	12/19	3/19	2/19	2/19

a. [ ] = exceeded proposed MFL criteria; [shaded] = met proposed MFL criteria
b. IR = Indicator Region
c. MFL Criteria for peat-forming wetlands are -1.0 feet below ground for more than 30 days; MFL criteria for marl-forming wetlands are -1.5 feet below ground for more than 90 days
d. PF = Permanently Flooded

Base Cases and Alternatives Results

1995 and 2020 Base Cases. The 1995 Base Case is the recommended flow target for Biscayne Bay. Increased regional water demands in the 2020 Base Case reduced the total amount of water discharged to Biscayne Bay by approximately 12 percent as compared to the 1995 Base Case (**Table 47**).

Table 47. Total Mean Annual Flows Discharged into Northern, Central, and Southern Biscayne Bay for the Base Case and Alternative Simulations during the 31-Year Simulation Period.

Area	Average Annual Flow (ac-ft x 1,000)						
	1995 Base Case[a]	2020 Base Case		2020 with Restudy		LEC-1	
		Flows	Change from Target	Flows	Change from Target	Flows	Change from Target
Northern Bay	312	298	-4%	241	-23%	259	-17%
Central Bay	434	335	-23%	252	-42%	269	-38%
Southern Bay	223	215	-4%	247	11%	267	20%
Totals	969	848	-12%	740	-24%	795	-18%

a. The 1995 Base Case is the recommended flow target for Biscayne Bay

2020 with Restudy and LEC-1. Performance of the 2020 with Restudy and LEC-1 alternatives showed total mean annual surface flows delivered to the bay was reduced by 24 and 18 percent, respectively, as compared to the 1995 Base Case (**Table 47**). These reductions in flow were caused primarily by construction of the C-4 structures which reduced the amount of water discharged through S-25B and the Miami Canal into central Biscayne Bay. As a result, the largest reductions in flow occurred in this area of the bay under the 2020 with Restudy and LEC-1 alternatives (**Table 47**).

In contrast, flows delivered to southern Biscayne Bay increased by 11 and 20 percent for the 2020 with Restudy and LEC-1 alternatives, respectively, as compared to the 1995 Base Case. This increase in water flow to southern Biscayne Bay was the result of incorporation of the water reuse components contained within both the 2020 with Restudy and LEC-1 alternatives (**Table 47**).

Incremental Results

Significantly lower mean annual flows were delivered to Biscayne Bay as a whole during the 2005 and LEC-1 Revised simulations compared to the target (1995 Base Case). The reductions were 21 and 18 percent for 2005 and LEC-1 Revised simulations, respectively (**Table 48**). These results, however, varied region by region within the bay. In northern Biscayne Bay, mean average annual flows remained near 1995 Base Case values during the 2005 simulation, increased in the 2010 and 2015 simulations, and then decreased in the LEC-1 Revised simulation due to Lake Belt Project components coming on-line. The most striking results occurred in central Biscayne Bay during the 2005 simulation where total flows delivered to the bay dropped by more than 39 percent compared to the 1995 Base Case (**Table 48**). This was due to construction of the C-4 structures, which significantly reduced flows from S-25B into the Miami Canal and central Biscayne Bay. These values increased during the 2010 and 2015 simulations, but decreased again during the LEC-1 Revised simulation, in part due to Lake Belt Project components coming on-line. In contrast, in southern Biscayne Bay, water reuse projects increased flows to the south by 20 percent during the LEC-1 Revised and improved estuarine conditions in this portion of the bay.

Table 48. Total Mean Annual Flows Discharged into Northern, Central, and Southern Biscayne Bay for the Incremental Simulations during the 31-Year Simulation Period.

Area	Average Annual Flow (ac-ft x 1,000)										
		1995 Revised Base Case		2005		2010		2015		LEC-1 Revised	
	1995 Base Case[a]	Flows	Change from Target	Flows	Change from Target	Flows	Change from Target	Flows	Change from Target	Flows	Change from Target
Northern Bay	312	312	0%	300	-4%	347	11%	340	9%	259	-17%
Central Bay	434	430	-1%	263	-39%	341	-21%	321	-26%	263	-39%
Southern Bay	223	222	0%	203	-9%	219	-2%	217	-3%	268	20%
Totals	969	964	0%	766	-21%	907	-6%	878	-9%	790	-18%

a. The 1995 Base Case is the recommended flow target for Biscayne Bay

Biscayne Aquifer Minimum Flows and Levels

Base Cases and Alternatives Results

All of the base cases and alternatives showed the ability to meet the proposed minimum canal operational levels for the Biscayne aquifer MFLs for the 31-year simulation period (**Table 49)**. These results indicated that the Biscayne aquifer was not threatened by saltwater intrusion in any of these simulations.

Table 49. Number of Times Minimal Minimum Flows and Levels Operational Criteria Were Not Met for the Biscayne Aquifer.

Canal/Structure	Minimum Canal Operation Levels to Protect Against MFL Violations[a]	Number of Times MFL Criteria Not Met			
		1995 Base Case	2020 Base Case	2020 with Restudy	LEC-1
C-51/S-155	7.80	0	0	0	0
C-16/S-41	7.80	0	0	0	0
C-15/S-40	7.80	0	0	0	0
Hillsboro/G-56	6.75	0	0	0	0
C-14/S-37B	6.50	0	0	0	0
C-13/S-36	4.00	0	0	0	0
North New River/G-54	3.50	0	0	0	0
C-9/S-29	2.00	0	0	0	0
C-6/S-26	2.00	0	0	0	0
C-4/S-25B	2.20	0	0	0	0
C-2/S-22	2.20	0	0	0	0

a. Duration criteria: water levels within the above canals may fall below the proposed minimum operational level for a period of no more than 180 days per year

Summary of Minimum Flows and Levels

Lake Okeechobee

MFLs were met in Lake Okeechobee for the 1995 and 2020 Base Cases, the 2020 with Restudy, and the LEC-1 alternatives, as well as the 2005 through 2020 incremental simulations. As a result, the MFL criteria are not expected to be exceeded even if the LEC Plan were not implemented. Therefore, neither a MFL recovery plan nor a prevention strategy is required for Lake Okeechobee.

The Everglades

In contrast, MFL criteria were not met for 12 of 19 selected monitoring sites located within the Everglades for both the 1995 and 2020 Base Cases. A MFL recovery plan will be needed for these areas. Features of this plan are presented in **Appendix J**.

Analyses of the 2020 with Restudy and LEC-1 simulations showed major improvements in the ability to meet the proposed MFL criteria by 2020. Incremental modeling results showed improvements in meeting MFLs within the northern Everglades by 2010 and 2015 as a result of construction of the Everglades Construction Project and the EAA Storage Reservoirs. MFLs were met for the majority of sites located within Everglades National Park by 2020 as a result of construction and operation of 50 percent of the Lake Belt Storage Area projects. By 2020, only two Everglades monitoring sites out of 19 did not meet the proposed MFL criteria.

Biscayne Aquifer

All of the base case and alternative simulations met the proposed minimum canal operational levels for the Biscayne aquifer for the 31-year simulation period. The Biscayne aquifer was not threatened by saltwater intrusion due to the inability to maintain coastal canals levels in any of these simulations. As a result, the proposed minimum canal operational levels are not expected to be exceeded even if the LEC Plan is not implemented. Therefore, neither a MFL recovery plan nor a prevention strategy is required for the Biscayne aquifer at this time.

Summary of Modeling Results for Natural Areas

Lake Okeechobee. Implementation of the WSE schedule in Lake Okeechobee resulted in a number of hydrologic improvements that should benefit the overall ecology of the ecosystem. These improvements began in 2005 and LEC planning targets were met by 2015.

St. Lucie and Caloosahatchee Estuaries. Construction of regional reservoirs combined with water management improvements in Lake Okeechobee by 2010 resulted in significant reductions in the number of high volume discharge events that impact both the St. Lucie and Caloosahatchee estuaries. These hydrologic improvements should help to maintain salinity regimes that will provide significant ecological benefits to both ecosystems.

Lake Worth Lagoon. Construction of STA-1E and other improvements to the regional system resulted in a significant reduction in the number of high volume discharge events that impact the Lake Worth Lagoon.

Holey Land and Rotenberger Wildlife Management Areas. In the EAA, completion of the Everglades Construction Project and EAA Storage Reservoirs, and implementation of rain-driven water delivery schedules for the Holey Land and Rotenberger WMAs provided significant ecological benefits to these overdrained areas by 2010.

WCA-3A and WCA-3B. Completion of the Everglades Construction Project, construction of the EAA Storage Reservoirs, and implementation of rain-driven water delivery schedules within northern WCA-3A reintroduced sheetflow to the northern Everglades system and met NSM-defined hydrologic targets in northern WCA-3A by 2010. These improvements should provide significant ecological benefits to this historically overdrained area of the Everglades system. In addition, WCA-3B and southern WCA-3A showed gradual improvements over time and came close to meeting NSM-defined targets by 2020.

Everglades National Park. Modeling results showed gradual improvement over time in providing increased flows to Everglades National Park. Beginning in 2005, a significant improvements in both the distribution and volume of water delivered to northeast and northwest Shark River Slough occurred. By 2010, the ability to meet NSM hydroperiod targets was significantly improved within northeast and central Shark River Slough, with near full recovery by 2020 (100 percent of the slough matched the NSM hydroperiod target by 2020). In the Rockland marl marsh, significant hydroperiod improvements were noted beginning in 2005 within this overdrained area. These improvements continued through 2020.

Florida Bay. Results also showed that major improvements occurred over time in the ability to provide increased flows toward western Florida Bay and Whitewater Bay. These increased flows should provide significant ecological benefits to areas that have been subject to reduced flows as a result of construction of the C&SF Project.

SYSTEMWIDE PERFORMANCE

Regional water budgets provide a useful means of comparing results of different model simulations. Primary water budget component maps are shown for the 1995 Revised Base Case (95BSRR); the 2005 (2005R), 2010 (2010R), and 2015 (2015R) incremental; and the LEC-1 Revised (2020R) simulations in **Figures 30** through **34**. **Table 50** provides a description for flow arrows depicted on the water budget component maps. The number next to each description refers to the numbered arrow on the primary water budget components key (**Figure 29**). The key reflects all the flow arrows on the water budget maps, while each individual map reflects only those arrows relative to that particular simulation.

Note that the water budget maps show mean annual flows averaged over the 31-year simulation period. They do not depict the desired timing of flows. In order to simplify these maps, flows at several structures are often lumped and represented by a single arrow. These maps are intended for informational purposes only and are not intended to be measures of performance of particular simulations.

Table 50. Description of Flow Arrows on the Primary Water Budget Components Maps.

No.	Description
	Lake Okeechobee
	Area = 728 square miles = 466,000 acres
1	Rainfall on Lake Okeechobee
2	Evapotranspiration from Lake Okeechobee
3	Net Inflows to Lake Okeechobee including Kissimmee River, Taylor Creek, and Nubbin Slough inflows plus S236 runoff plus net delta storage term, which accounts for historical inflow minus outflow not otherwise accounted for
4	Outflow to North of Lake Okeechobee Storage Reservoir
5	Inflow from North of Lake Okeechobee Storage Reservoir
6	Injection to Lake Okeechobee ASR system
7	Recovery from Lake Okeechobee ASR system
8	Change in Lake Okeechobee storage
	Caloosahatchee Basin and Estuary
9	Water supply from Lake Okeechobee to meet Caloosahatchee Estuary minimum environmental flows
10	Regulatory releases from Lake Okeechobee to Caloosahatchee Basin
11	Portion of Lake Okeechobee regulatory releases that go directly to Caloosahatchee Estuary
12	Portion of Lake Okeechobee regulatory releases that are stored in C-43 Basin Storage Reservoir
13	Water supply from Lake Okeechobee towards meeting Caloosahatchee Basin demands
14	Caloosahatchee Basin runoff
15	Caloosahatchee Basin runoff that returns to Lake Okeechobee
16	Portion of Caloosahatchee Basin runoff that flows to Caloosahatchee Estuary and contributes towards meeting environmental demands of estuary
17	Portion of Caloosahatchee Basin runoff that flows to Caloosahatchee Estuary and does not contribute towards meeting estuary demands (i.e. is undesirable flow because it exceeds estuarine targets)
18	Portion of Caloosahatchee Basin runoff that flows to C-43 Basin Storage Reservoir
19	Outflow from C-43 Basin Storage Reservoir and ASR towards meeting environmental demands of Caloosahatchee Estuary
20	Water supply from Caloosahatchee Basin Storage Reservoir and ASR towards meeting Caloosahatchee Basin demands
21	Sum of flows that contribute towards meeting estuarine target
22	Environmental targets for Caloosahatchee Estuary
	St. Lucie Basin and Estuary
23	Water supply from Lake Okeechobee to meet St. Lucie Estuary minimum environmental flows
24	Regulatory releases from Lake Okeechobee to St. Lucie Basin
25	Water supply from Lake Okeechobee towards meeting St. Lucie Basin demands
26	Backflows to Lake Okeechobee from C-44 Basin Storage Reservoir
27	St. Lucie Basin runoff

Table 50. Description of Flow Arrows on the Primary Water Budget Components Maps.

No.	Description
28	St. Lucie Basin runoff that returns to Lake Okeechobee
29	Portion of St. Lucie Basin runoff that flows to St. Lucie Estuary and contributes towards meeting environmental demands of estuary
30	Portion of St. Lucie Basin runoff that flows to St. Lucie Estuary and does not contribute towards meeting estuary demands (i.e. is undesirable flow because it exceeds estuarine targets)
31	Portion of St. Lucie Basin runoff that flows to C-44 Basin Storage Reservoir
32	Outflow from C-44 Basin Storage Reservoir towards meeting environmental demands of St. Lucie Estuary
33	Water supply from C-44 Basin Reservoir towards meeting St. Lucie Basin demands
34	Non-C-44 Basin runoff that contributes towards meeting estuarine targets
35	Sum of flows that contribute towards meeting estuarine target
36	Environmental targets for St. Lucie Estuary
Everglades Agricultural Area	
	Area = 948 square miles = 606,720 acres (Includes Holey Land and Rotenberger WMAs and STAs)
37	Rainfall on EAA
38	Evapotranspiration from EAA
39	Releases from Lake Okeechobee for Big Cypress Seminole's demands
40	Releases from STA-6 and Rotenberger WMA for Big Cypress Seminole Reservation demands
41	Inflow to EAA from Western Basins
42	Water supply from Lake Okeechobee that contributes towards meeting environmental needs in Rotenberger WMA and the Everglades Protection Area
43	Water supply from Lake Okeechobee that contributes towards meeting environmental needs in Rotenberger WMA
44	Water supply from Lake Okeechobee, through EAA, that contributes towards meeting environmental needs in the Everglades Protection Area
45	Regulatory releases from Lake Okeechobee to EAA Storage Reservoir, Compartment 2
46	Water supply from Lake Okeechobee, through EAA, that contributes towards meeting LEC Service Areas' water needs
47	Regulatory releases from Lake Okeechobee, through EAA, to the WCAs (through the STAs where applicable, but is undesirable flow because it exceeds WCA environmental targets)
48	Agricultural water supply to EAA from Lake Okeechobee
49	Runoff from EAA to Lake Okeechobee
50	Ground water flow from the LEC Service Areas to EAA
51	Water supply from EAA to LEC Service Areas (including STA-1E)
52	Inflows to EAA from C-51 Regional Ground Water ASR and West Palm Beach Catchment ASR
53	Inflows to EAA from C-51 Regional Ground Water ASR and West Palm Beach Catchment ASR to meet agricultural demands
54	Inflows to EAA Storage Reservoirs from C-51 Regional Ground Water ASR and West Palm Beach Catchment ASR
55	Ground water flow from WCAs back to EAA
56	Runoff from EAA to WCAs (through STAs where applicable) - excluding L4 wraparound flows through S-140
57	Water supply from EAA Storage Reservoirs that contributes towards meeting environmental needs
58	Runoff from EAA to WCAs (through STAs where applicable) through L4 wraparound and S-140
59	Ground water flow from EAA to Big Cypress National Preserve
60	Runoff from EAA to EAA Storage Reservoirs, Compartment 1
61	Agricultural water supply from EAA Storage Reservoirs, Compartment 1
62	Change in EAA water storage

Table 50. Description of Flow Arrows on the Primary Water Budget Components Maps.

No.	Description
	Water Conservation Areas
	Area = 1,320 square miles = 844,800 acres
63	Rainfall on WCAs
64	Evapotranspiration from WCAs
65	Runoff into WCAs through G-155
66	Runoff from northern Big Cypress National Preserve and runoff from EAA routed westward, which flow through structures into WCAs
67	Overland flow from Big Cypress National Preserve into WCAs
68	Ground water flow from WCAs to Big Cypress National Preserve
69	Structural outflows to southern Big Cypress National Preserve
70	Regulatory releases to Everglades National Park
71	Overland flow from WCA-3 to Everglades National Park
72	Releases to Everglades National Park that contribute towards meeting environmental targets
73	Ground water flow (includes levee seepage) from WCAs to Everglades National Park
74	Water released from WCA-3 to Lakebelt storage areas to help meet environmental targets in WCA-3
75	Water supply from WCAs to help meet LEC Service Areas' demands
76	Runoff from LECSA 2 to WCA-3
77	Water released from WCA-2B to Lakebelt storage areas to help meet environmental targets in WCA-2B
78	Ground water flow (includes levee seepage) from WCAs to LEC Service Areas
79	Runoff from LECSA 1 to WCA-1 (through STAs where applicable)
80	Change in WCAs water storage
	Big Cypress National Preserve
	Area = 1,196 square miles = 765,440 acres
81	Rainfall on Big Cypress National Preserve
82	Evapotranspiration from Big Cypress National Preserve
83	Runoff inflow from the north
84	Flow from SR-29 Canal out of western boundary of Big Cypress National Preserve
85	Overland flow from Big Cypress National Preserve towards Florida Bay
86	Ground water flow from Big Cypress National Preserve towards Florida Bay
87	Southward overland flow from Big Cypress National Preserve to Everglades National Park
88	Ground water flow from Everglades National Park to Big Cypress National Preserve
89	Change in Big Cypress National Preserve water storage
	Everglades National Park
	Area = 972 square miles = 622,080 acres
90	Rainfall on Everglades National Park
91	Evapotranspiration from Everglades National Park
92	Eastward overland flow towards Whitewater Bay and Florida Bay
93	Ground water flow in southwest direction towards Florida Bay and Whitewater Bay
94	Southward overland flow from Everglades National Park towards Florida Bay
95	Southward overland flow from the southwestern area of LEC service areas to the Everglades National Park
96	Levee seepage from Everglades National Park that is returned to the park along the eastern boundary
97	Ground water flow to LEC service areas
98	Pumped outflow into LEC service areas from proposed S-357 Structure in 8.5 Square Mile Area

Table 50. Description of Flow Arrows on the Primary Water Budget Components Maps.

No.	Description
99	Inflow of new water to Everglades National Park from the Lakebelt storage areas, seepage collection, and WCA-3 and WCA-2B excess through structures and overland flow buffer zones along the eastern boundary of the park (S-174; S-332 A,B,D; S-356 A,B), excluding levee seepage from the park that is pumped back into the park
100	Change in Everglades National Park water storage
Lower East Coast Service Areas	
	Area = 2,088 square miles = 1,336,320 acres (Includes L-8 Basin)
101	Rainfall on LEC service areas
102	Evapotranspiration from LEC service areas
103	Net pumpage for water supply
104	Water provided from the reuse of reclaimed water
105	Overland flow to Biscayne Bay
106	Ground water flow to Biscayne Bay
107	Structural flow to Biscayne Bay
108	Ground water flow from Broward County to tide
109	Structural flow from Broward County to tide
110	Overland flow from Broward County to tide
111	Overland flow from Palm Beach County to Lake Worth Lagoon
112	Ground water flow from Palm Beach County to Lake Worth Lagoon
113	Structural flow from Palm Beach County to Lake Worth Lagoon
114	Ground water flow from Northern Palm Beach County to tide
115	Structural flow from Northern Palm Beach County to Loxahatchee River
116	Overland flow from Northern Palm Beach County to Loxahatchee River
117	Overland inflow from the north
118	Runoff from LEC service areas to Lake Okeechobee
119	Injection into ASR systems
120	Recovery from ASR systems
121	Change in LEC service areas water storage

Figure 29.
Removed for Security Purposes

Figure 30.
Removed for Security Purposes

Figure 31.
Removed for Security Purposes

Figure 32.
Removed for Security Purposes

Figure 33.
Removed for Security Purposes

Figure 34.
Removed for Security Purposes